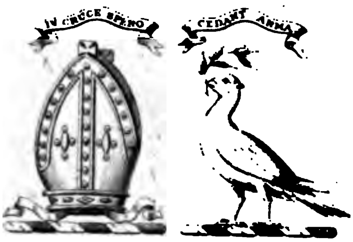

Francis Hubert Barclay

PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

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GEOLOGISTS' ASSOCIATION.

VOLUME THE THIRTEENTH.

1893-94.

EDITED BY

A. MORLEY DAVIES,

A.R.C.S., B.Sc., F.G.S.

(*Authors alone are responsible for the opinions and facts stated in their respective Papers.*)

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CONTENTS.

New Species Figured and Described in this Volume.

Sections Described and Measured.

* Not measured.

LIST OF ILLUSTRATIONS.

CORRIGENDA ET ADDENDA.

Page 2, line 5, *for* "W. D. Best" *read* "E. Best."
„ 29, line 3 from bottom, and page 30, line 26, *for* "Futtlerer" *read* "Futterer."
„ 52, last line, *for* "Trigonocarpus" *read* "Trigonocarpon."
„ 110, fig. 15, *add to explanation*, "*q.* quartz ; *f.* felspar ; *m.* muscovite ; *b.* biotite."
„ 137, line 3 from bottom of text, *for* "rubby" *read* "rubbly."
„ 142, line 10 from bottom, *for* "Greensands" *read* "Greensand."
„ 150, line 18 from bottom, *for* "Selinite" *read* "Selenite."
„ 151, footnote, *after* "p." *add* "431."
„ 189, line 17 from bottom, *for* "Multocrescis" *read* "Multicrescis"
„ 209, lines 6 and 5 from bottom, *for* "Messrs." *read* "Mrs.," *and omit* "and A. J. Maslem."
„ 212, line 23, *read as two lines*—
"1. Chloritic Marl
"Do. (Upper Greensand) . . (*Pecten Asper*)."
„ 212, footnote, *after* "see also" *insert* "Jukes-Browne's *Building of the British Isles* and."
„ 214, line 7 from bottom, *for* "Faxoë Island" *read* "Faxe, on the island of Seeland."
„ 215, line 5, *for* "Faxoë" *read* "Faxe."
„ 222, line 3 from bottom, *omit* "all."
[The statement in line 45 applies to the south-west of England only, and even there the conditions may be explained in a different manner.—W.F.H.]
„ 225, line 18, *for* "100" *read* "10."
„ 227, footnote, *for* "Roy" *read* "Ray."
„ 234, lines 30-33, *omit* "Before . . southern counties," *and for* "It" *read* "The Chalk Rock."
[The statement to be omitted refers to the Totternhoe Stone.—W.F.H.]
„ 239, line 1, *for* "Culebra, S.W. Indies" *read* "Culebra Island, West Indies."
„ 258, line 1, *for* "aquivalvis" *read* "æquivalvis."
„ 273, line 1, *before* "would" *insert* "I."
„ 280, line 20, *for* "Russell" *read* "Russel."
„ 289, line 4, *for* "Rynchonella" *read* "Rhynchonella."
„ 292, line 18 from bottom, *for* "peregra" *read* "pereger."
„ 298, line 12, *after* "order" *read* "to."
„ 298, line 25, *for* "Radnorshire" *read* "We t Herefordshire."
„ 300, line 17, *for* "county" *read* "country."
„ 302, line 4, *for* "recognised . . . of the" *read* "recognised and described the lithological character and significance of the."
„ 307, line 1, *for* "Western" *read* "Eastern."
„ 307, line 19, *for* "Eastern" *read* "Western."
„ 307, line 30, *for* "Ventnor" *read* "Wentnor."
„ 307, line 47, *omit* "also."
„ 308, line 31, *for* "elsewhere" *read* "everywhere."
„ 308, line 41, *for* "west" *read* "east"
„ 309, line 6, *for* "it contact" *read* "in contact."

Page 311, line 5, *Conophrys*, Call. is stated by Linnarsson to be identical with *Shumardia*, Billings (Linnarsson, *Geol. Mag.*, dec. 2, vol. vi, p. 188).
„ 313, line 8 *for* " 1886 " *read* " 1885."
„ 315, legend to fig. 10, *insert* " *l* " *before* " Upper Ludlow Rocks."
„ 316, table. *In last column*, " 2 " *and* " 3 " *should be opposite* " Whittery Ash " ; " 4 " *opposite* " Hagley Shale " ; *and* " 5 " *opposite* " Hagley Ash."
„ 317, line 28, *for* " Fig. 11 " *read* Plate viii, Fig. B."
„ 318, line 26, *omit* " 6."
„ 321, legend to Fig. 11, *for* " Pantamerus " *read* " Pentamerus."
„ 322, line 35, *for* " species " *read* " fragments."
„ 323, line 21, *for* " decidedly rare " *read* " less abundant."
„ 325, line 24, *for* " in the " *read* " on the."
„ 326, line 31, *omit* " had previously."
„ 328, line 26, *after* " Linley Brook " *insert* " ‡ " *and add footnote* " ‡ *Quart. Journ. Geol. Soc.*, vol. xix, 1863, p. 229."
„ 329, last line, *before* " Rep." *insert* " Watts."
„ 330, footnote †, *add* " *Mid. Nat.* vol. xv, 1892, p. 217."
„ 331, line 44, *after* " Jones " *add* " and Dr. Ricketts."
„ 334, line 38, *for* " age of the " *read* " ages of the various."
„ 335, line 20, *for* " moderately " *read* " fairly."
„ 341, line 28, *for* " is a laccolite " *read* " is a compound laccolite."
„ 342, lines 5 and 6, *for* " almost flat " *read* " anticlinally curved."
„ 342, Fig. 22, *for* " Ymys " *read* " Ynys."
„ 343, line 14, *for* " isolated " *read* " isolated, as well as the component laccolites themselves."
„ 347, line 1, *after* " Silurian " *insert* " of this area."
„ 347, line 27, *for* " Lower " *read* " Middle."
„ 348, bottom of second column, *for* " Olenellidian " *read* " Taconian."
„ 350, line 5, *after* " line " *insert* " *," *and for footnote read* " * *Geol. Mag.*, vol. iv., 1867, p. 302."
„ 350, line 7 from bottom, *before* " the " *insert* " all."
„ 350, line 2 from bottom, *for* " 1854 " *read* " 1874."
„ 351, line 11 from bottom, *before* " older " *insert* " actually."
„ 352, line 29, *for* " in the future " *read* " when fully worked out."
„ 354, line 6, *for* " volcanic " *read* " igneous."
„ 359, line 4 from bottom, *for* " Microscopically " *read* " Macroscopically."
„ 373, line 6 from bottom of text, *for* " this " *read* " the."

PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

ORDINARY MEETING.

FRIDAY, NOVEMBER 4TH, 1892.

Rev. Prof. J. F. BLAKE, M.A., F.G.S., President, in the Chair.

The donations to the Library since the last meeting were read, and the thanks of the Association accorded to the several donors.

The following were elected Members of the Association:—J. W. Carr; W. H. Gates; J. W. Martin.

The meeting then resolved into a Conversazione. The chief objects exhibited were:—

Photographs illustrative of the Geology of Hertfordshire, by JOHN HOPKINSON, F.L.S.

Photographs of geological interest from Brittany, by the Rev. Prof. BLAKE.

Photographs and Map of the recent eruption of Etna, and specimens of Geikielite, by F. W. RUDLER, F.G.S.

Photographic transparencies of North Wales, by HENRY PRESTON.

Rocks from Ranmer Common; Fossils from Moel-y-Tryfan, Taplow, and Wotton; and Leaves from the Bournemouth Beds, by THOS. LEIGHTON, F.G.S.

Fluor Spar from Weardale, by G. W. CARD, F.G.S.

Foraminifera from the Taplow Phosphatic Chalk, by FREDERICK CHAPMAN.

Carboniferous Crinoids from North Staffordshire, by PHILIP ROSCOE.

Rock Specimens from the Auvergne district, by W. J. ATKINSON, F.G.S., and H. FLECK.

Rock Specimens from Dartmoor, Brent Tor, and Piedmont, by A. M. DAVIES, F.G.S.

A new Geological Map of Scotland, by W. D. BEST, on behalf of Sir ARCHIBALD GEIKIE, F.R.S.

Jurassic Building-stones, and a copy of William Smith's "Strata Identified," by H. B. WOODWARD, F.G.S.

A case of precious Opal and Meteorites, and a Bread-crust Bomb from Vulcano, by J. R. GREGORY.

Miocene Mollusca from Russia, by G. F. HARRIS, F.G.S.

Specimens of *Palæospondylus gunni* from the Old Red Sandstone of Caithness, by A. SMITH WOODWARD, F.G.S.

Amygdaloidal Porphyrite from Fendoch Burn, near Crieff, and a mass of *Nummulites complanatus* from Cuisse-la-Motte, by C. DAVIES SHERBORN, F.G.S.

A large series of Palæolithic implements from Surrey and Sussex, by W. J. LEWIS ABBOTT, F.G.S.

A large collection of Fossils from the Chalk, by JAMES FOX.

ORDINARY MEETING.

FRIDAY, DECEMBER 2ND, 1892.

Rev. Prof. J. F. BLAKE, M.A., F.G.S., President, in the Chair.

The donations to the Library since the last meeting were read and the thanks of the Association were accorded to the several donors.

The following were elected Members of the Association:—C. J. Harcourt; Miss A. Acutt; Rev. W. H. Booth; Ivon Braby; Newton Braby; F. J. M. Palmer; J. E. Westerman; Miss M. C. Crosfield; Miss L. A. Jarvis.

The following paper was then read:—

"On the Lower Greensand Area to the North of the 'Rookery' Fault between Wotton and Dorking," by Prof. G. S. BOULGER, F.L.S., and THOS. LEIGHTON, F.G.S.

Specimens were exhibited by the authors in illustration of their paper.

ORDINARY MEETING.

FRIDAY, JANUARY 6TH, 1893.

Rev. Prof. J. F. BLAKE, M.A., F.G.S., President, in the Chair.

The donations to the Library were read, and the thanks of the Association were accorded to the several donors.

The following were elected Members of the Association:—Henry Mountcastle; John Duce; Robert Ardley; G. E. Dibley; C. W. Andrews; Rev. R. A. Bullen; A. Ebbels; W. H. Bell; J. B. Morgan; F. G. Bryant.

Messrs. H. H. French and Clement Reid were elected Auditors for the year.

The President referred to the loss the Association had sustained by the deaths of Sir Richard Owen and Mr. Thomas Davies.

A lecture was delivered by the Rev. H. N. HUTCHINSON, M.A., F.G.S., entitled, "An Attempt to Restore some Extinct Animals," which was illustrated by the oxy-hydrogen lantern.

ON THE LOWER GREENSAND AREA TO THE NORTH OF THE "ROOKERY" FAULT BETWEEN WOTTON AND DORKING.

By Prof. G. S. BOULGER, F.L.S., F.G.S., and THOS. LEIGHTON, F.G.S.

[*Read December 2nd, 1892.*]

INTRODUCTION.—Our apology for bringing forward this paper at the present stage of our observations is, that the section which forms the key to our position has been twice visited by the Association in recent years, and upon each occasion the reporters, who are also the authors of this paper, have found it impossible to describe this section in accordance with the official map of the Geological Survey. We have now satisfied ourselves that the section in question, that at the entrance to the "Rookery," is of Folkestone age, and that this view is in accord with the evidence of numerous other sections we shall describe in the area to which this paper refers. We hope on a future occasion to connect our observations with the area to the east, and, as will be here shown, we at present anticipate no difficulty in doing so.

Our case is that the southern line of the Folkestone area in this district, hitherto shown doubtfully* as passing from the fault to the north of Wotton, round the north of the mill-pond at Westcott, thence eastwards across Milton Heath to Dorking, should, in fact, be moved bodily south to the fault, with a possible area of Sandgate Beds at the southern end of the Lower Greensand district on the Horsham Road to the south of Dorking. In the west our line will start from the entrance to the "Rookery," where the Bargate Stone dips under the Folkestone Beds, now mapped as Hythe, and continues eastwards along the line of the fault. We have proved the presence of Hythe Beds at one low level within this area, and we believe this section will show a small inlier here; but we must leave precise details of mapping to the officers of the Survey, who can pass freely over enclosed ground, which we have necessarily been unable to do. We trust to bring forward sufficient evidence in this paper, however, to show that our view is the only possible one. We are not pertinacious as to the existence of Sandgate Beds in the area to the east; we only put forward the view, as will be presently shown, to account for certain conditions which obtain there. The point is, in any case, quite a minor one. The fault which bounds

* The boundary is marked by a dotted line on the official map, signifying that there is some doubt as to its exact position.

the area to the south we have ventured to call the "Rookery" fault, as it is an extremely important one, and appears to require a name for convenience. It is the great east-and-west fault to the north of Leith Hill, and forms the easterly prolongation of the Pease Marsh anticlinal.

THE ROOKERY SECTION.—This section, at the western end of Westcott Heath, forms the key to our position. It shows coarse, clean, sharp sand, mostly bright orange, but with white inclusions, between highly contorted lines of ironstone. Lines of ironstone are plentiful here, a phenomenon which appears, from similar sections, to be usual at this horizon (low in the Folkestone Beds) in this district. The ironstone lies, as described, in wavy lines of varying thickness, probably along lines of infiltration. There is, apparently, much false-bedding, but no clayey partings or sandstone. This section lies between about 280 feet at the floor of the pit and the 300-foot contour, which touches it at the top. To the west the ground falls to 266·7 feet at the bridge over the Pipp Brook; it then rises to between 280 and 300 feet where the Bargate Stone, in the section on the road to Wotton Hatch, is seen, inclined ten degrees N.E. The distance is a little over a furlong, due west. It is obvious, then, that the Rookery Section must be in Folkestone Beds. The stratigraphical evidence requires what the lithological evidence bears out. On the occasion of the excursion to Wotton this summer the point was suggested by us on the ground for discussion, in order to elicit any possible contrary view; but Prof. Logan Lobley at once called attention to the facts here demonstrated, and the only possible condition of things to account for the Survey mapping, namely, a fault along the line of the Pipp Brook, when suggested for the sake of argument by one of us, was disposed of as absurd by all present. Further, it rests with those who oppose our view to show the existence of such a fault before such a condition of things can be put in as evidence.

THE NEW SECTIONS.—For the sake of easy reference, we have lettered these as they occur from east to west. It will be seen that in the Survey Map the Rookery fault is shown as dying out about half a mile to the east of the Horsham Road, south of Dorking. We followed the line of the fault here right up to the marsh, but could find no trace of the Atherfield Clay. Immediately to the west of the road the Weald Clay is seen in a small section, and on the other side of the road there is an old sand-pit on the face of the low escarpment. Following the escarpment eastwards we found the surface soil light, sandy, and scored by water channels to an extent that must render cultivation difficult. Below, the presence of clay is shown by the oak trees, beyond the line of the fault, however. Of course, the Atherfield Clay may lie below the sandy "run" of the hill just referred to, but we saw no surface indications of it, and there is no section.

(*A*) The section in the sand-pit at the southern end of the cutting on the Horsham Road, and immediately to the north of the Rookery fault, shows nothing but buff clayey sand, with some ironstone in places; the sand is rather fine, and what is called "dirty" (that is, not sharp), with thin beds of clay occasionally, but more usually with clayey partings, sometimes with inclusions of a coarser and cleaner sand.

From this point at the base of the escarpment the Horsham Road to Dorking passes through a cutting for the space of about a furlong, and there is a series of sections on either hand. The surface at the cutting is a little above the 300-foot contour, rising sharply to the east, the highest part of the road showing a bench-mark of 291 feet, where the cutting may be from 20 to 30 feet deep on the eastern side. The dip is to the north. Although, therefore, we might reasonably expect to find lower beds here than at Westcott Heath, there is not much room to spare, since this locality lies very little to the south. Speaking generally, we may say that the base of the clear, sharp, coarse sand with ironstone, which we call undoubted Folkestone Beds, falls slightly from a little above 300 feet O.D., at the Horsham Road section to 280 feet or less at Westcott Heath, but the latter locality lies about a furlong to the north, and the dip is strongly to the north.

(*B*) The first section on the eastern side of the cutting is, as would be expected, similar to the section (*A*), then, however, more sandy beds appear to come in, accompanied by a thick bed of iron sandstone, from ten to fourteen inches thick. These beds may not be in place, but since such alternations of sedimentation are characteristic of the Sandgate Beds, with which we are at present inclined to class the lower horizons of this cutting, we did not stop to investigate that point, since further the Folkestone Sands would lie on the higher ground just above. Immediately to the north the clayey sands again appear, and are seen on both sides of the road. In general appearance these beds are strikingly different from the Folkestone Sands: they are chiefly olive-drab or dirty-brown in colour, sometimes becoming almost green; they are coherent; and the occasional thin clay bands and clayey partings stand out on the weathered face of the cutting. The sands, although sometimes coarse, are finer in the lower beds; they are always more or less "dirty," with much ironstone throughout, the iron is indeed the only character they possess in common with the true Folkestone Sands.

(*C*) Near the northern end of the Horsham Road cutting, there is a small pit, shown on the six-inch map, on the eastern side of the road. The section extends to the top of the cutting and the 300-foot contour passes over the lower bank on the opposite side of the road, that is, on about the level of the junction of the undoubted Folkestone Sands with the sands with clay below: this junction we believe to be shown in the pit. The lower beds are just like those last described; but, above them, marked off by a small ledge due to the different weathering, are coarse, loose, sharp, clean sands, red and buff in colour, still with much iron, but more diffused than in the beds below, giving a brighter colouration. There is neither clay, clayey partings, nor sandstone. This is the last section on the eastern side of the road; a little further on, on the opposite side, however, traces of the same thing appear in the lower bank, which has shown nothing to the south but the clayey sands as above described. There is false-bedding throughout the whole of these sections, but possibly more markedly in the Folkestone Sands.

As we were working from north to south, we made out the junction on the western bank before we had seen the larger and clearer section on the other side, and we have, therefore, no doubts as to our facts.

(*D*) At the eastern end of "The Nower" Estate where a new road over the site of Holloway Farm runs into Coldharbour Lane, just opposite the new road, there is a small section in undoubted Folkestone Sands, just above the 300-foot contour. It is a very small exposure, and since it lies a little north of section (*C*) it may show a higher horizon. It shows the usual buff, coarse, sharp sand, without sign of clay, but with some silver sand; there is a good deal of iron-staining and rather less ironstone; false-bedding as usual. The section is strikingly similar in character to several along the S.E.R., from Dorking eastward to Redhill.

(*E*) About twenty chains to the north of this spot, at the corner of Coldharbour and Hampstead Lanes, there is a section in undoubted Hythe Beds at 244 feet above O.D. This is the section which we have said may mark an inlier. It shows the thin-bedded, siliceous-cemented, flaggy sandstone, so well-known as characteristic of the Hythe Beds of this district. It will be noticed that this locality lies somewhat north of the Westcott Heath or Rookery section, but forty feet lower in level, and that with higher ground to south, west, and east, there is a steady fall of the surface towards Dorking, where Folkestone Sand is known to exist under the town. The fall of the surface, then, must be less than the dip. Still a tongue of Hythe Beds may possibly come round from the west along the course of the Pipp Brook; but this, which hardly seems probable to us, could only be determined by a detailed survey.

It is difficult, in words, to express the difference between the Hythe and Folkestone Beds of this district. Both are sands mainly, still nobody would hesitate for a moment in correlating the specimen produced from this spot as undoubted Hythe. In the field the two formations are perfectly distinct and recognisable. The general characters of the Hythe Beds may be stated as follows: They consist of bedded sandstones, often with cherty veins; sometimes in thin flaggy layers interbedded with sand of the same character; sometimes in thick beds with much chert. In clear sections the beds are usually white, with a grey appearance on close examination, due to dark specks of glauconite; and owing to the iron in this mineral, they usually weather brown or red. Mr. Topley pointed out, at the excursion to Leith Hill, in 1890, that they have always been described as remarkable for the absence of calcareous matter.

(*F*) In enclosed ground at Buryhill there is a section of undoubted Folkestone Sand, in the plantation beyond the second lodge from the entrance on Milton Heath. The section is along a private road through the park in a cutting through the "feature" of Buryhill and the "Nower" down to the Weald Clay on the other side of the fault, which has here formed a kind of inland cliff. The clay on the south side holds up the waters of Buryhill pond. Mr. Drew says (Weald Memoir, p. 233) that at Berry Hill, which we take to be the same locality, there is not good evidence of the fault. To us the evidence appeared extremely instructive; but then the sections may not have been opened when the survey was made. Where the road first dips into the cutting there are sharp, coarse sands, buff and iron-stained silver sands, with a little ironstone, very much as in section (*D*). Lower down the ironstone increases, as usual, and just where the clayey sands should appear the section is built up by a substantial brick wall. Was this wall erected to preserve the carriage-drive from the nasty habit of sand to slip over clayey beds? Or was it only to keep up the broken strata at the fault? Or do the owners of parks build walls at great expense indiscriminately, for reasons altogether apart from the nature of the sub-soil? No doubt, the wall at this point is a geological misfortune. The section lies approximately between the 280 and 300-foot contours, the earlier and higher part a little to the north of, and the more southern and lower part due east of, the Rookery section; the brick wall being certainly at a lower level than 280 feet.

(*G*) The last section we have to describe is in the pit at Rokefield, in the area mapped by the Survey as Folkestone Sand. It lies nearly half a mile to the north of the line of the Rookery section, a little below the 280-foot contour, and shows the highest beds of the Folkestone Sands and a junction with the Gault, which, previous to the visit of the Association this summer, although suspected, was not recorded. The sands are sharp and coarse, there is no clay in the Folkestone Sands below the junction; there is no ironstone, but much diffused iron, which gives a brilliant crimson and purple colour to the sands. The following notes were made by one of us a month after the excursion, but in October the junction was too much obscured by weathering to admit of detailed description.

"The field and roadside above this pit have always, from the vegetation, denoted the presence of the Gault; before the occasion of the excursion, however, the writer had never been able to make out a good section of the junction in the pit itself. Just before this visit, however, some extensive drainage works had been carried out along the road above, and, possibly in connection therewith, a considerable slip had taken place at the eastern side (the inside) of the pit itself. This slip has displayed a clear section of the junction between the Gault and Folkestone Sands, of which details are as follow :—

		From the surface
Gault.	1.	Gault Clay, with much Glauconite and a few Phosphatic (?) Nodules.
	2.	Sandy Blue Clay, with Glauconite.
Folkestone Beds.	3.	Coarse Orange Sands, with small Pebbles and Clayey Partings.
	4.	Red and Buff Sands.
		To bottom of the pit.

"The lithological change from sand to clay is abrupt; beds 2 and 3 are junction-beds of no great thickness, and might very well be the result of the mingling of material on the sea floor at a sudden change of sedimentation. The Gault is as usual very fossiliferous, the chief forms being *Ammonites* (*Hoplites*) *interruptus* (Brug.)."

A lane leads to the north-east through this pit, and beyond the cottage at Bushy Plat we found what would be described, in geological language, as a "gravel," composed of fragments of Hythe Sandstone. This lies on the Gault, and is doubtless connected with an earlier stage of the history of the Pipp Brook. Referring to the Gault of this district, it should be noticed that Mr. Whitaker (Weald Memoir, p. 149) records several feet of an interesting "junction-bed" a quarter-mile north-west of Gomshall railway station, of which there appears no sign in the Rokefield Pit.

Previous Work in the District.—The references to the geology of this district in Mr. Topley's excellent Memoir of the Weald are not numerous, and since the chief sections upon which we rely were evidently not open at the time that survey was made, more than thirty years ago,* it will be convenient to discuss those sections which are recorded with the general consideration of the new ones we have now described. The notices are chiefly by the late Mr. Drew, and it is clear from his remarks that the important Rookery section, which is the key to the others, was not open when he described, so accurately, the important sections in the immediate neighbourhood and on the same high-road, through the Bargate Stone and Hythe Beds (Weald Memoir, p. 233). The different view taken by the Survey

* The map was published in 1862.

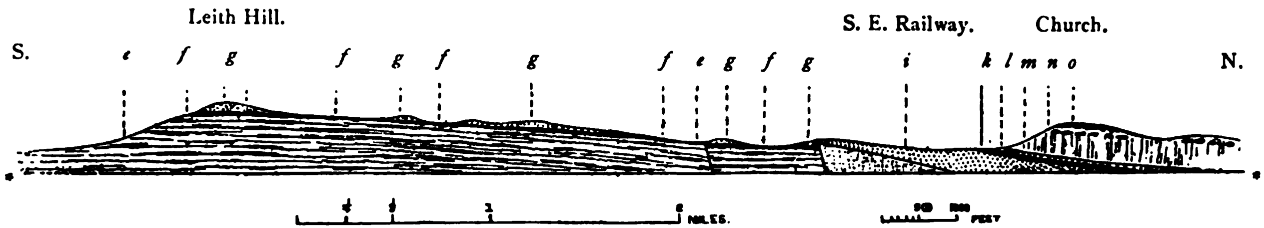
to that of Mr. C. J. A. Meÿer as to the correlation of the Bargate Stone may here be fittingly noticed, since it bears upon what we shall first discuss. Mr. Meÿer in his classic paper on the Lower Greensand of Godalming, read before this Association in 1868, placed the Bargate Stone at the bottom of the Folkestone Sands (Fig 2 of his paper), and further claimed (page 10) that the pebble beds marked an unconformity with the beds below. The officers of the Survey placed the Bargate Stone at or near the top of the Hythe Beds, which may make little difference where, as in our district, the Sandgate Beds are absent. The Survey admits that the Sandgate Beds are absent to the west of our area, near Albury (Drew, Weald Memoir, p. 134), but does not admit the unconformity; although the section, as described, appears rather to support Mr. Meÿer. Here is the passage:

"The next noteworthy sections are in the railway cuttings near Albury, where, however, there is no clay, the ferruginous sands of the Folkestone Beds being almost at once underlain by Bargate Stone, the two separated only by a bed of dark, coarse pebbly sand of varying thickness, the grains of which are almost wholly peroxide of iron. This may be the equivalent of the clay in other parts."—*Drew.*

This is a point we should be glad to see explained; indeed, we should be glad to know how the absence of the Sandgate Beds is accounted for without an unconformity. Immediately before his remarks just quoted, Mr. Drew says:—

"From Dorking to Shiere there is no clay between the sand, and in some places the dividing line is very indefinite; indeed, from Dorking to Westgate Street (Westcott), the Lower Green sand, with the exception of the Atherfield Clay, is much the same from top to bottom." Again, on page 141, referring to the Folke stone Beds we read, after a reference to the sections along the Dorking and Horsham Railway: "There are numerous sections of these sands along their outcrop westwards, but none of great importance." No geologist who had seen the sections we have here described could have written so, and no author who had seen the Horsham Road (*C*), Hampstead Lane (*D*), and Rookery sections, could write that the Lower Greensand of the district was much the same from top to bottom. If then our examination of this country, where the Sandgate Beds were hitherto supposed to be absent at the east, and the Bargate Stone to be dying out at the west, throws any light on the controversy as to the geological horizon of the latter formation, it is, that both it and the Sandgate Beds immediately underlie the Folkestone Sands, the one on the west, the other to the east. Why, then, should we not take a middle view and place the Bargate Stone as the equivalent of the Sandgate Beds in the west? On the whole it must be admitted that our evidence, such as it is, is rather in favour of Mr. Meÿer, although we find

SECTION FROM LEITH HILL TO RANMER COMMON.



Horizontal Scale. Vertical Scale

o Clay with flints, etc.	*i.* Folkestone Beds. } Lower Greensand.
n. Chalk, with flints.	*g.* Hythe Beds. } Lower Greensand.
m. Chalk, without flints.	*f.* Atherfield Clay. } Lower Greensand.
l. Upper Greensand.	*e.* Weald Clay.
k. Gault.	* Sea Level.

Reproduced from the Survey Memoir, with the correction as observed by the authors. The black line following under *i* to the N. of the fault marks the probable position of the Bargate Stone; under that are the Hythe Beds. The black line *f* to S of the fault represents the Atherfield Clay, as indicated nothing for or against his views as to the unconformity. This little digression leads naturally to the discussion of the lower beds of the Horsham Road section, which we suggest may be of Sandgate age.

Speaking generally, it may be said that sandy clay is the distinguishing feature of the Sandgate Beds, and although a composition of that nature is not in itself evidence upon which to correlate sections in widely different areas, it becomes of some importance when, as in this case, the over and underlying formations are of different and well ascertained character. The verbal descriptions of memoirs convey little idea of the difference between the sands of the Folkestone and Hythe Beds ; but, nevertheless, in the field the differences are unmistakable. No doubt the references of the Weald Memoir to sections of sands in this district are somewhat perplexing. We shall presently show, however, that this is due only to the want of evidence which caused the whole area to be mapped as Hythe. For purposes of comparison, therefore, we must turn to neighbouring sections, concerning which there is no dispute. The general character of the Folkestone Sands is well known, and we presume there will be little question that the sections of sands without clay, which we have described on the same level approximately as the Rookery section, belong to that formation. But what, then, about the important series of clayey sands seen below the sand in the Horsham Road cutting? (Sections *A* to *C*). Now it should be remembered that the Folkestone Beds are extremely constant in character. Although somewhat different at Folkestone itself, from containing layers of siliceous limestone and chert, already near Saltwood, but six miles to the west, we find them described in these words (Weald Memoir, p. 139): "To the west of Saltwood the beds change in character. The stone disappears, as also for the most part does the chert, and they become simply false-bedded sands, with occasionally irregular lines of ironstone ; this character the beds retain for many miles to the west." There is not a Folkestone section, to our knowledge, in Surrey, which would not answer to this excellent description in the main. The Memoir notices some unimportant differences in composition about Maidstone and other places, but when our area is reached there is a noteworthy paragraph (page 141) by Mr. Topley: "The cutting in the Horsham and Dorking railway gives a fine section of these beds. At first sight they appear to be lying flat, with occasional lines of false-bedding, dipping N. These, however, are true bedding (dip 20° N.), and the dip has brought the lines of false-bedding into a nearly horizontal position. The bedding (true and false) is marked by thin layers of pinkish clay and clayey sand. The beds are crossed by coloured lines of infiltration and by irregularly-branching lines of iron-sandstone." This section lies just east of the area we are now describing, and since we have not examined it in the light of our recent discoveries, we prefer not to express too decided an opinion at present. The beds described by Mr. Topley would appear to be the same as those of our sections (*A*) and (*B*) on the Horsham Road; therefore, if the latter are not Sandgate Beds they are certainly Folkestone, and not Hythe, which is, after all, the chief point of this paper. On page 121 of the Memoir, under Hythe Beds, we find the following: "By the roadside at Cockham Mills there are thirty feet of rather coarse sand with some thin ironstone. About Reigate Heath the beds are sandy throughout, and in Betchworth and Deepden Parks there is some sandstone. In several places south and south-west of Dorking the beds are seen. Generally they are sand with ironstone; in the road near Holloway Farm there is buff sand, partly calcareous, with thin beds of clay, overlying sand with layers of ironstone."—*Drew.* "The railway cutting east of Dorking exposes a fine section of these beds."—*Topley.*

The neighbourhood of Holloway Farm is now a suburb of Dorking, on rising ground, between the 260 and 280-foot contours; whilst at the same time "the road near Holloway Farm" would describe the locality of our sections on the high road from Dorking to Horsham and Brighton, the well-known coach road. It is scarcely credible that, if that is the case (and the sections are identical) the locality was not more particularly defined. It can make little difference, however, as the beds would certainly be the same, and we are here in direct conflict with the Survey as to the lower beds with clay, which we must presume from Mr. Topley's last note follow under the clayey sands he has classed as Folkestone in his railway section to the east. Now this is the point. Upon what evidence are buff sands with clayey partings, otherwise all but identical in composition with the Folkestone Sands, placed in the Hythe Beds? The Hythe Beds are frequently described as sands, and properly so; but it is sand of an entirely different character, well known in this district, since the sandstone beds form the chief local road-metal.* There are sections practically all over the outcrop, and piles of the material in almost every lane and road. Now, it appears clear from the preceding sentence of the same quotation from the Memoir, wherein Mr. Drew describes several places in our area (south and south-west of Dorking) as showing the Hythe Beds consisting generally of "sand with ironstone," that the absence of the key-section at the Rookery has caused him, not at all unnaturally, to misread the whole of the sections, since we have now, we hope, shown that these sections are in the Folkestone Sands. It will further be recollected that we describe a section of true Hythe Beds

* The road-metal, which was examined by the excursion party on the High Road, near Wotton Hatch, in July last, of somewhat "mixed" character, is obtained from the "drift" pit, near Crossways.

within a short distance of Holloway Farm at 244 feet O.D. (section *E*). Hence we are forced to the conclusion that there is absolutely no evidence in this district for classing such beds as Hythe. Folkestone they may be, but not Hythe. The next paragraph on the same page of the Memoir discloses an additional advantage, if our view is accepted; since the considerable change in composition in such a very small distance is not required. Indeed, this argument appears to us unfortunate, and to require explanation. An entire change in the character of a sand, as great as the differences between the Rookery (Folkestone) and Wotton (Hythe) sections, within two miles at the most, and without evidence of passage beds, requires a stretch of the imagination we are not prepared to grant. This is quite another matter to the oncoming of a series of Pebble Beds like the Bargate Stone, which can be easily accounted for as a geological phenomenon.

We claim to have proved then, that, in the neighbourhood of Holloway Farm and on the Horsham Road, the clayey sands are overlaid by sands corresponding in character to the Rookery section in the Folkestone Sands, and at approximately the same level, 300 feet O.D.; also that the same clayey sands are underlaid in the same district by beds of grey bedded sandstone of undoubted Hythe age, proved close at hand at 244 feet O.D.

We do not rest our opinion upon this evidence alone, however, but upon the correspondence of the general succession of beds our reading will imply, with sections to the west, recorded in the Weald Memoir.

On page 122 Mr. Drew says:—

"The following very good section of the whole of the Hythe Beds may be seen in the lane west of St. Martha's, and leading to Halfpenny Farm:—

Folkestone Beds .	. Ferruginous Sand.
Sandgate Beds	. Clayey Sand, with large pebbles and small patches of fuller's earth.
Hythe Beds . .	. Brownish-grey Sand, with ironstone.
	Etc."

Again, on page 135 we have a section in the railway cutting north of Rake showing—

Folkestone Beds .	. Buff Sand.
Sandgate Beds .	. Buff Sand, with drab clay in patches.
	Etc.

In concluding our review and discussion on the beds we have classed as of Sandgate age, we have only to draw attention to the remark at the bottom of page 129 of the Memoir, where we read that when the Sandgate Beds become too thin to be separately mapped they have been included in the Folkestone Beds. This may be necessary in the district we have described to the south of Dorking

Our discussion on the last subject has diverged into so many byeways, that few references to the district in the Weald Memoir remain to be discussed. It is worth noticing, however, that on page 141 there is described a series of exposures of Folkestone Beds at St. Martha's, Guildford, and on the south of the Hog's Back from Guildford to Farnham, corresponding precisely in character to those we have described between Dorking and Westcott.

We find then the following general succession of beds in this district:

Gault	
Folkestone Sand	Brightly-coloured Ferruginous Sands, with silver sand and more or less ironstone (carstone), particularly in the lower part.
Sandgate Beds (in the east)	Drab, buff, and brown clayey sand, thin clays, sands with beds of carstone; iron stone in places throughout, duller in colouration.
Bargate Stone (in the west)	Calcareous grit, with lydites, etc.
Hythe Beds	White, speckled and grey bedded sandstone, weathering brown, with cherty veins, interbedded with white and grey sands.

This succession accords fairly well with the section given on page five of Mr. Meÿer's paper. What however is still more noteworthy is its correspondence with the Petersfield section on Plate IV of Mr. Topley's Memoir.

It may be objected that the "feature" from the Rookery eastward to Dorking through Bury Hill and the Nower Parks, which we maintain to be Folkestone, is obviously continuous with that from the Red Hill "pass" westward by Woodhatch, Reigate, and Betchworth, which is Hythe, and that it is contrary to the general rule for an escarpment to be made up of more than one formation. To this it may be answered (i) that, connected as the Pease Marsh anticlinal and the great strike-fault from Abinger to the Brighton Road admittedly are with the upheaval of the Weald, they are vastly more ancient than the line of the Lower Greensand escarpment, the one dating probably from Miocene, the other only from Post-Pliocene times; (ii) that there is nothing unusual in a fault affecting the line of an escarpment, as do, for example, the dip-fault at Merstham, and this very fault itself to the east of Leith Hill; (iii) that it is admitted that this strike-fault follows the line of the escarpment, which, as usual, follows the line of strike, along the disputed bit of country; (iv) that we do not deny a considerable lithological uniformity between Hythe and Folke-stone beds in this area; and that, therefore (v), though here (as is also usually the case), much of the upthrow side of the fault has been planed down uniformly to the downthrow side, we can well imagine the "raw edge" of the upthrow to have determined the run of the escarpment, even though it may (as we hold) traverse two distinct series, when those series, though distinct in name and in age, are so similar in the resistance they can offer to subaërial denudation.

We shall no doubt be charged with presumption in attempting to correlate beds upon lithological evidence only; accordingly, as this is distinctly a question for the field, we have here recorded our challenge, and we invite our opponents to meet us at an excursion to the district next summer and to fight out the question on the spot.

ANNUAL GENERAL MEETING.

FEBRUARY 3RD, 1893.

Rev. Prof. J. F. BLAKE, M.A., F.G.S., President, in the Chair.

Messrs. B. B. Woodward and W. H. Davis were appointed Scrutineers of the ballot.

The following Report of the Council for the year 1892 was then read:—

THE numerical strength of the Association on the 31st of December, 1892, was as follows:—

Honorary Members	15
Ordinary Members:—	
a. Life Members (Compounded)	150
b. Old Country Members (5s. Annual Subscription)	9
c. Other Members (10s. Annual Subscription) .	347
Total . . .	521

During the year forty-seven new Members were elected. The Council regrets that the Association has lost eight Members by death:—Sir Richard Owen; James Plant; Dr. M. W. Taylor; Thomas Hart; J. J. Winser; W. Atkinson; P. C. Nixon; W. H. Moberley. A special letter of condolence has been sent to the representatives of the late Sir Richard Owen, whose many kindnesses to the Members of this Association will be gratefully remembered. The deaths of Dr. M. W. Taylor and Mr. Thomas Hart will cause a blank at many of our future excursions, when the memory of their genial companionship will come upon us.

During the past year the receipts from ordinary sources have amounted to £214, whilst the ordinary expenses have amounted to £244; but this sum includes a payment of £48 outstanding from 1891, which should be deducted: the actual expenditure of the year would then be £196, showing a balance of £18 in favour of the Association, with no outstanding liabilities whatsoever, and a sum of £15 6s. 11d. due from Stanford. This result cannot be considered unsatisfactory, seeing that the amount received from annual subscriptions (£167) is the smallest for several years past—a circumstance due to the fact that so many of our new Members do not become annual subscribers, but pay the life-composition fee of £5 5s. Notwithstanding that considerable effort has been made to collect all the subscriptions, there still remained £33 outstanding at the close of the year.

A sum of £36 19s. has been invested in Nottingham

GEOLOGISTS' ASSOCIATION.

Dr. Income and Expenditure for the Year ending December, 1892. Cr.

	£	s.	d.		£	s.	d.
To Balance from 1891	17	18	7	By Printing "Proceedings"	121	12	6
" Life Compositions	36	15	0	" " Monthly Circulars	18	10	0
" Admission Fees	19	10	0	" Illustrating "Proceedings" and Circulars ...	15	14	5
" Annual Subscriptions	167	0	0	" Miscellaneous Printing	10	6	11
" Dividends on Nottingham Corporation Stock...	20	8	10	" Postages	44	12	3
" Advertisements	2	16	8	" Addressing	11	7	7
" Sale of Publications	3	19	10	" Library	1	19	0
" Sale of Record	4	19	0	" Attendance, Gas, etc., at Evening Meetings ...	12	10	6
" Sale of "Paris Basin"	14	14	11	" Insurance	1	1	0
				" Stationery	5	4	11
				" Miscellaneous Expenses	1	9	6
				" Purchase of £37 3s. 1d. Nottingham Corporation Stock	36	19	0
				" Cash in hand	6	15	3
	£288	2	10		£288	2	10

We have this day examined the Accounts of the Treasurer of the Geologists' Association, and we find the above Statement to be correct.

(Signed) H. HUTCHINS FRENCH, CLEMENT REID, } *Auditors.*

13th January, 1893.

Corporation Stock, consisting of so much of the life-subscriptions and proceeds of sales of the "Record" and "Paris Basin" as had been received up to the time of the last Council Meeting of the year.

During the year five numbers of your "Proceedings" were issued to Members (parts 9 and 10 being issued together), thus completing vol. xii. These numbers comprise 218 pages, including preliminaries, with four plates and twenty-eight other illustrations. You are indebted to Mr. A. Smith Woodward for the plate illustrating his paper.

Many valuable additions have been made to the Library during the past year. The List of Societies exchanging with ours has been revised. The whole question of the Library is at present under the consideration of the Council. Your thanks are again due to Mr. Litchfield for the assistance he renders to the Librarian.

The following is a list of the Papers read at the evening meetings:—

"The Geology of the Country round Stirling," by HORACE W. MONCKTON, F.G.S.

"On Zones," by HORACE B. WOODWARD, F.G.S.

"Notes on the New Admiralty Section, with additions to the Thames Valley Fauna," by W. J. LEWIS ABBOTT, F.G.S.

"The Gold of Quartz-Veins—an Aqueous Hypothesis," by J. LOGAN LOBLEY, F.G.S.

"A General Sketch of the Geology of Carnarvonshire and Anglesey," by the Rev. Prof. J. F. BLAKE, M.A., F.G.S.

"Notes on the Westleton Beds near Henley-on-Thames," by H. J. OSBORNE WHITE.

"On the Lower Greensand Area to the North of the 'Rookery' Fault between Wotton and Dorking," by Prof. G. S. BOULGER, F.L.S., and THOMAS LEIGHTON, F.G.S.

On February 5th your President delivered his annual address, on "The Evolution and Classification of the Cephalopoda—an account of recent advances."

Lectures were delivered in April and in June—the first by J. W. GREGORY, F.G.S., on "American Scenery in its Geological Relations"; the second by F. W. RUDLER, F.G.S., on "The Fathers of British Geology." Both of these lectures were illustrated by the oxy-hydrogen lantern.

Your thanks are due to these lecturers.

A Conversazione was held on November 4th.

The following Museums were visited during 1892:—

British Museum (Natural History), on March 19th, when Mr. Arthur Smith Woodward, F.G.S. (in the unavoidable absence of Dr. H. Woodward, F.R.S.), delivered an address on the Pleistocene Mammalia.

The Museum of W. H. Hudleston, Esq., F.R.S., on March 26th, when his well-known collections of Oolitic fossils were examined under his guidance. On this occasion the opportunity was taken of presenting to Mr. Hudleston, as an old friend of the Association, an address of congratulation on his election to the Presidency of the Geological Society.

The Museum of Practical Geology (Jermyn Street), on April 2nd, when the collections in the Rock Gallery were explained by Messrs. A. Strahan, F.G.S., J. J. Harris Teall, F.R.S., and H. B. Woodward, F.G.S.

The Devizes Museum, on April 16th, when the geological and archæological collections were explained by Messrs. W. H. Bell, J.P., F.G.S., and Cunnington.

The Nottingham Museum, on June 6th, when the collections were explained by Mr. J. W. Carr, F.G.S.

The following is a list of the excursions made during the past year, detailed reports of which will be found in numbers 8 and 10 of vol. xii. of the "Proceedings":—

DATE.	PLACE.	DIRECTORS.
March 5th.	Hornchurch.	T. V. Holmes, F.G.S.
April 16th to 19th (Easter).	Devizes, Swindon, and Faringdon.	The President, W. H. Bell, J.P., F.G.S., F. J. Bennett, F.G.S., G. J. Hinde, Ph.D., F.G.S., and H. B. Woodward, F.G.S.
April 30th.	Hendon and Finchley.	H. Hicks, M.D., F.G.S.
May 7th.	Walthamstow.	J. Walter Gregory, F.G.S.
May 14th.	Wendover.	Upfield Green, F.G.S., and H. B. Woodward, F.G.S.
May 21st (whole day).	Lenham.	G. Dowker, F.G.S., and Clement Reid, F.L.S.
May 28th.	St. Albans.	J. Hopkinson, F.G.S., and W. Whitaker, F.R.S.
June 4th to 7th (Whitsuntide).	Nottingham.	The President and Lieut. G. Elmsley Coke, R.N.
June 18th.	Down.	W. E. Darwin, F.G.S., and W. Whitaker, F.R.S.
June 25th (whole day).	Woburn Sands and Sandy.	A. C. G. Cameron, H.M. Geological Survey.
July 9th.	Wotton and Dorking.	Prof. G. S. Boulger, F.L.S., and T. Leighton, F.G.S.
July 16th (whole day).	Taplow.	J. H. Blake, F.G.S.
July 25th to 30th (long excursion).	North-West Carnarvonshire and Anglesey.	The President.

The excursions of the past year were particularly interesting. That to Down, on June 18th, was attended by an exceptionally large party, without doubt the largest on record. Your thanks are most emphatically due to Mrs. Darwin and to the other members of her family for their hospitality and kindness in permitting the Association to visit Mr. Darwin's home—kindness of which the large attendance at the excursion showed the recognition. Your thanks are likewise due to the directors of the excursions; also to the following ladies and gentlemen for assistance and hospitality:—Messrs. John Mowlem and Co., at Hornchurch; Mr. W. H. Hudleston, F.R.S., and Mrs. Hudleston, on March 26th; Mr. A. J. Jukes-Browne, F.G.S., at Devizes; Dr. H. Hicks, F.R.S., and Mrs. Hicks, at Hendon; Messrs. Firbank and Co., at Wendover; Mr. J. Hopkinson, F.G.S., and Mrs. Hopkinson, at St. Albans; Mr. J. W. Carr, F.G.S., Mr. R. Enfield and Miss Enfield, Mr. H. Fisher and the Clifton Colliery Co., Mr. Frank Rayner, Mr. Percy Cropper, Capt. Holden, and Mr. J. Shipman, F.G.S., at Nottingham; Mr. De B. Crawshay, at Down; Mr. and Mrs. Page, Mr. Geo. Dames, Mr. W. B. Dixon, Mr. E. J. Leeds Smith, and Mr. A. J. G. Swinney, on June 25th; Mr. W. H. Grenfell, M.P., at Taplow; and the District Superintendent of the L. and N. W. Railway at Chester, and the Manager of the Penrhyn Slate Quarries, during the Long Excursion.

The interest in the excursions continues to show a healthy increase, thanks chiefly to the improvement made in the illustrating of the circulars and the energy displayed by your Excursion Secretary.

On March 4th your Council, acting under bye-law xviii., thought it expedient to present the small collection of Pleistocene Mollusca, given to the Association in 1860 by Mr. Pickering, part to the British Museum, and part to the Museum of Practical Geology, from whom letters of thanks have been received.

In the summer, your Council announced a proposal for the formation of a "Geological Photographs Committee," in connection with that of the British Association, and on the same lines, with the addition only that a copy of each photograph should be deposited in the Library of this Association. The movement has not been so extensively taken up as was hoped, nor as its usefulness deserves, but sufficient promises of support have been received to warrant a commencement.

Your thanks are again due to the Council of University College for the use of their rooms for our meetings, and for according permission to hold the Conversazione in their Library.

The changes in our House List, as shown on the balloting papers now in your hands, are considerable; and your thanks are especially due to the Rev. Prof. J. F. Blake, who has held your presidency for two years. During his term of office Professor Blake has worthily upheld the dignity of the chair, has proved himself an energetic and tireless leader of excursions, and has already contributed to your proceedings a remarkably concise account of one of the most difficult groups of animals—the Cephalopoda. Such summaries of information on definite groups are of the greatest possible value for reference, and save endless time to an Association of workers such as ours.

Mr. W. Bolger Gibbs, your Treasurer, has tendered his resignation, the duties of office demanding more time at his hands than he can reasonably spare from a busy life. He has most conscientiously carried out the responsibilities of his office, and you will be gratified to know that he has promised to continue his valuable advice as to the investment of your funds, as from time to time may be required.

Mr. F. A. Bather, your Editor, also tenders his resignation, temporary ill-health preventing him from continuing the office. Your thanks are due to him for the energy he has displayed in keeping your "Proceedings" well up to date.

Your thanks are also due to the following Members of your Council, who retire on this occasion:—Rev. Prof. T. G. Bonney; Prof. G. S. Boulger; Mr. Upfield Green; Mr. J. W. Gregory (by reason of his absence in Somali-land); Mr. H. W. Monckton.

The names of those suggested by your Council to fill the vacant offices will be found on the balloting papers.

On the motion of Dr. G. J. Hinde, F.G.S., seconded by Mr. W. J. Atkinson, F.G.S., the Report was adopted as the Annual Report of the Association.

The scrutineers reported that the following were duly elected as Officers and Council for the ensuing year:—

PRESIDENT:
Horace B. Woodward, F.G.S.

VICE-PRESIDENTS:

T. V. Holmes, F.G.S.	Miss C. A. Raisin, B.Sc.
W. H. Hudleston, M.A., F.R.S.	Rev. Prof. J. F. Blake, M.A., F.G.S.

TREASURER:
R. S. Herries, M.A., F.G.S.

SECRETARIES:
C. Davies Sherborn, F.G.S., F.Z.S.
Thomas Leighton, F.G.S.

EDITOR:
A. Morley Davies, F.G.S.

LIBRARIAN:
John Bradford, F.G.S

COUNCIL:

F. A. Bather, M.A., F.G.S.	E. T. Newton, F.G.S.
James Fox	F. W. Rudler, F.G.S.
H. Hutchins French, F.G.S.	J. Slade, F.G.S.
W. Bolger Gibbs, F.R.A.S.	W. Topley, F.R.S.
John Hopkinson, F.L.S., F.G.S.	A. Smith Woodward, F.G.S.
C. Johnson, F.C.A.	A. C. Young.

On the motion of Mr. B. B. Woodward, F.G.S., seconded by Mr. A. H. Williams, the thanks of the Association were unanimously voted to the officers and members of Council retiring from office, to the auditors, and to the scrutineers.

The President then delivered his address, entitled "The Bases of the Classification of Ammonites."

On the motion of Mr. A. E. Salter, seconded by Mr. L. Belinfante, B.Sc., it was unanimously resolved that the President's address should be printed *in extenso.*

This terminated the Annual Meeting.

ORDINARY MEETING.

FRIDAY, FEBRUARY 3RD, 1893.

HORACE B. WOODWARD, F.G.S., President, in the chair.

The following were elected Members of the Association:—A. M. Hiddon; J. F. C. Snell; Miss Ethel Skeat; G. P. Mudge.

There being no paper, the proceedings then terminated.

ORDINARY MEETING.

FRIDAY, MARCH 3RD, 1893.

HORACE B. WOODWARD, F.G.S., President, in the chair.

The donations to the library, since the last meeting, were read, and thanks were accorded to the several donors.

The following were elected Members of the Association:—G. Abbott; S. Farnfield, F.G.S.; Alfred Absell, junr.; A. G. Wildy; Edw. Johnson; H. N. Maynard; J. W. Crossley.

Mr. GEORGE BARROW, F.G.S., delivered a lecture on "The Highland Schists and their Metamorphism," which was illustrated by the oxy-hydrogen lantern.

A specimen of *Gyrodus cretaceus*, Ag., from Warlingham, was exhibited by Mr. DIBLEY.

ORDINARY MEETING.

FRIDAY, APRIL 7TH, 1893.

HORACE B. WOODWARD, F.G.S., President, in the chair.

The donations to the library, since the last meeting, were read, and thanks were accorded to the several donors.

The following were elected Members of the Association:—The Rev. H. N. Hutchinson; F. W. Chant Hobrow; Lt. B. W. Bowdler, R.E., F.G.S.; James Morris.

The following papers were read:—

"The Sandgate Landslip," by W. TOPLEY, F.R.S.

"Glacial Sands at Highgate Archway," by W. J. LEWIS ABBOTT, F.G.S.

Mr. TOPLEY's paper was illustrated by numerous photographs, shown by the oxy-hydrogen lantern. Mr. ABBOTT exhibited a series of specimens in illustration of his paper.

ON THE BASES OF THE CLASSIFICATION OF AMMONITES.

By Prof. J. F. BLAKE, M.A., F.G.S.

Being the Presidential Address delivered 3rd February, 1893.

AMMONITES, at present, form the happy hunting ground of theorists. Their varieties are almost infinite, and the resemblances between them are many-sided; what then can be simpler or more attractive than to pick out a series of forms which seem to be connected in one way or another, and give the series a name? Assuming the principle that all the forms are in some way genetically connected,—either as direct descendants, or as having a common ancestor more or less remote in time—it follows that there is a high probability that some of the series so selected represent the facts of nature. But how are we to distinguish the true from the false? What principles are to be our guide? Some of the more general, as the similarity of ontogeny to phylogeny,[1] and the law of acceleration of development, have been already laid down, and scarcely admit of controversy; but these are not sufficient. For the detailed work that has to be done, we want some more special principles which shall apply to the Cephalopoda as a class. I do not think that in thus limiting our view, for a time, to one particular group, we are warning off the student of evolution as a whole: for if we can place the history of any one group on solid grounds, we show at least that it is possible to discover such a history with the materials at our command. The principles we thus seek, must not be laid down on *a priori* grounds, but must be obtained by induction from as wide a review of acknowledged facts as possible. I hoped at one time that I should have been able to deal with the whole class; but now I have sorrowfully to confess, that, even after restricting myself to the Ammonites alone, I am not in a position to lay down any definite conclusions, but in view of the overwhelming mass of material to be dealt with, can only make some desultory observations which may, I hope, tend to elucidate the matter.

In the absence of any recognised representative of the Ammonites amongst living animals we have only the shell to deal with. The elements of the shell in which one Ammonite differs from another are as follows:—the *form*, the *size*, the *body-chamber*, the *aperture*, the *aptychus*, the *first chamber*, the *ornaments*, and the *sutures*.

As it is impossible to deal with all these fully in the course of

1 This principle has, however, been recently controverted.

an Address, some of them must be dismissed with few words. The length of the body-chamber was placed in the first rank by Suess when he began to divide the Ammonites[2], because it was specially distinctive amongst Triassic Ammonites, and its use as a generic character was extended by Waagen[3]; but little use has been made of it by other authors, partly no doubt because it cannot often be observed, and partly because it is not a very definite character. Its extreme length becomes a special character in *Arcestes*, and its extreme shortness in *Lytoceras*, but these genera are otherwise characterized. The length would also seem to be correlated with the amount of involution. If the interior part of the whorl is occupied by the previous whorl, the loss of space is apt to be made up for by the length of the last chamber; but no general rule can be laid down. The form of the aperture is another of the characters that cannot often be observed, and little use has been made of it except in special cases. Still rarer is the discovery of an aptychus: so that the assertion of its absence in any group, or its universal presence in another, is extremely hazardous; and in any case this character has to do with the larger groups, which are not at present attracting much attention. The form of the first chamber is one of the elements to which, as pointed out last year, Branco[4] attaches some importance; but this is rather in comparing Goniatites with Triassic and later Ammonites, and does not enter into the question of the classification of Ammonites as we have them in this country. There are left then—1, the form; 2, the size; 3, the ornaments; and 4, the sutures, on which I propose to say something in order.

1. THE FORM. Of this there are four elements:—(A) the amount of curvature; (B) the involution; (C) the thickness of the whorl; (D) the shape of its transverse section.

(A). *The amount of curvature.* Some years ago I wrote a Mathematical Paper "On the curves formed by Cephalopoda and other Molluscs"[5], in which I showed that the curvature can be determined, independently of all other elements, by drawing a straight line through the centre across the Ammonite, and determining the ratio of the intercept on the outer half-whorl (AB, Plate i, figs. 1, 2) to the intercept on the penultimate half-whorl (CD). This method assumes that the rate of curvature of the inner edge is the same as that of the outer. If this is not the case, the curvature can be represented, either by the ratio of the larger to the smaller of the two parts into which any diameter is divided by the centre, or by the square of the ratio of two diameters at right angles to each other.

2 Sitz. k.-k. Akad. Wiss. Wien, lii. 1865.
3 Benecke's Palæont. Beitr., Bd. ii. Heft. 2, 1869.
4 Palæontographica, Vol. xxvii. No. 12, 1880.
5 Phil. Mag., S. 5, vol. 6, 1878.

Now the greater this ratio, the less is the curvature[6] of the shell. From this a curious result is obtained, when we compare, for example, the figure of *Crioceras Duvalii* as given by D'Orbigny (Pl. i, fig. 2), with that of *Ammonites Largilliertianus* (Pl. i, fig. 1); we find that the ratio in the former is 1·56, while that of the latter is 1·86. In other words, there is more curvature in the open-whorled *Crioceras* than in a perfectly involute Ammonite. Indeed, as a general rule, we find the least curvature amongst the most involute shells, as though the overlapping of the whorls made up in part for the want of curvature. We must, therefore, be very cautious in saying, as Hyatt does, that Ammonites "uncoil" when we refer to their whorls being separate. They do not necessarily do so.

This may be very well shown by drawing the figure of an imaginary Ammonite with the whorls just in contact. (Pl. i, fig. 4.) Now, if without touching the outside, and without, therefore, interfering in any way with the curvature, we fix on the centre the apparent inward continuation of the whorls, we get a form resembling that of *Phylloceras* (Pl. i, fig. 3); if, on the other hand, we fix on the centre a pattern which cuts off the inner part of the whorls, we get a form resembling that of *Crioceras* (Pl. i, fig. 5): so that such an Ammonite is a veritable "transmogrificabilis." It demonstrates that the difference between the form of *Phylloceras*, *Arietites*, and *Crioceras* has nothing whatever to do with their curvature.

There are certain forms, such as *Ancyloceras* and *Scaphites*, in which the rate of curvature suddenly changes at one part of the shell; so that they may become straight, or even slightly reversed. Are we to look upon these as senile types, and their uncoiling a mark of degeneracy? It seems to me that such a shell as *Ancyloceras Renauxianus*, D'Orb. (Terr. crét., pl. cxxiii), negatives such a view; for all the vigour which produces knobs is found on the uncoiled part, and the sudden turn in all these forms is produced by a rapid increase of curvature. I have not been able to discover any observations which might throw light upon the question whether an *Ancyloceras* has at all periods of its life its peculiar shape, or whether its prolongation is an adult feature. If the former is the case, the hinder part of the body-chamber must be constantly absorbed, to enable the coiled part to increase after the formation of the straighter portion. Such an absorption is supposed by Hyatt to take place in a similar case, but it is to be noticed as against this view, that there are sutures in this straighter portion.

Before leaving these abnormal forms, attention may be called to the extraordinary parallelism there is between the *Cochloceras* and *Lobites* of the Trias, and the *Turrilites* and *Scaphites* of the

6 Some authors speak of a shell which attains a large diameter with *few* coils as a "quick-coiling" shell; such shells have less curvature than the "slow-coiling" ones.

Upper Cretaceous, and in a lesser degree between *Choristoceras* and the uncoiled *Toxoceras*, &c.; while the development of *Ancyloceras* characterizes two distinct epochs—the Callovian and the Neocomian. The significance of this will be discussed further on.

Turning now to the earlier whorls of the shell: if the curvature be estimated in a series of sections through the centre of the Ammonite, such as those given by Vacek in his "Fauna der Oolithe von Cap S. Vigilio"[7], by a comparison of the consecutive radii, it will be found by no means constant. There are invariably irregularities in the earlier whorls, and comparative constancy only sets in after a certain size is attained: the curvature of the last whorl being in some greater, and in some less than the average. So far as I have been able to trace them, there is always a period, while the shell is still small, at which there is an unusual increase in size, *i.e.*, a diminution of curvature; and it is immediately after this stage that greater regularity sets in. If a wider research should confirm this rule, we might consider it as connected with the life-history of the animal. For the curvature of the shell is brought about by the more rapid growth of the outside: hence a diminution of curvature means a more rapid relative growth of the inside (*i.e.*, the part nearer to the centre). It is still, I think, a moot point whether the outside of an Ammonite is dorsal or ventral, *i.e.*, whether it be curved in the opposite or in the same sense to a Nautilus. It may perhaps be suggested that the more rapid growth of the inside at a certain period of life is due to the development of the generative organs, and in this case they must be on the opposite side to those of the Nautilus, and the outside of the Ammonite may be dorsal.

(B). *The amount of involution.* This is one of the most important of the characters of the shell. When all is regular, the inner edge of the whorl represents a part of the same curve as the outer, but a part further back towards its origin, and one, therefore, of less rapid growth. The involution depends upon how much the inner edge is retarded, *i.e.*, on how far back in an ever more slowly growing series of points it stands. It follows, therefore, that unless some special irregularity supervenes, Ammonites are necessarily more evolute in their youth than in later life, for there is less possibility of lagging when the outer edge has not advanced so far. Thus there is nothing in the evolute character of the young to show that the radical of the race was evolute in any case. Those who, like Hyatt and Buckman, seek an evolute ancestor for every form, should show how any form can have an involute embryo, when there is an "ovisac" (so-called) in the centre of the whorl. That a shell may become more evolute in age than in middle life is certain, but this is because the inner edge changes its rate of coiling relatively to

7 Abhandl. k.-k. geol. Reichs, Bd. xii. Wien, 1886.

that of the outer edge. It is said by Hyatt that involution is characteristic of the acme of groups, and, when combined with compression, of their degeneration; while elsewhere he says that uncoiling is a geratologic character, which, as I have shown, depends for the most part, not on the lack of curvature, but on the lack of involution. So far as I can make out, this theory is first laid down, and then the species are placed in their proper position to suit it, without any proof that they actually occur in that order. All we seem justified in saying is that in any true genetic series we may expect that the involution will either remain constant, or constantly either increase or decrease, as we pass along the line of descendants.

(C). *The thickness*, *i.e.*, the diameter of the whorl from side to side. Whilst we have been dealing with the breadth of the whorl, we could not say much as regards its absolute rate of increase as the necessary measures involve the curvature as well; but as the Ammonites are coiled in one plane, we can measure the relative rate of growth by the increase of the breadth. We thus see that Ammonites might be divided into two groups which are parallel to the *longicones* and *brevicones* amongst *Orthocerata*, and distinguished as *compressed* and *depressed* forms respectively. There, is, however, some difficulty even in this, as the true rate depends on the length of the spiral, *i.e.*, on the rate of coiling. Nevertheless, in allied forms the thickness divided by the radius from the centre of the Ammonite may give us an approximate measure. There is, however, an important remark to be made in this connection. We know that in all *Orthocerata* the rate of increase is not constant, but the sides of the shell make a curve, concave towards the middle line, in the neighbourhood of the apex. The corresponding phenomenon to this is that the whorls of an Ammonite become naturally more compressed with growth. There is nothing, therefore, in the fact that the earlier whorls are more depressed, that should warrant the assumption that any particular species is derived from a more depressed ancestor, unless we are prepared also to admit the proposition that longicone Orthocerata are derived from brevicones, of which there is no indication in the order of their occurrence, some of the oldest being longicones.

(D). The last element of the shape is the particular pattern of the transverse section. This, of course, is largely dependent on the ornaments, and almost belongs to that class of character, so that it will be best to leave its discussion till later.

2. THE SIZE. We are so much in the habit of handling cabinet specimens that we fancy such must be ordinarily adult, and compare the characters of a series at about the same size. Yet there must be races of giants such as that culminating in the 4 ft. *Am. ganesa*, and races of dwarfs as *Am. trivialis* of the Lias, and it does not appear to me that either of these extremes is likely to be the progenitor of a new race of forms. Giants require for

their production a long continuance of favourable circumstances, with comparatively few competitors, and thus they gradually lose their elasticity, and are exterminated on the occurrence of new conditions. Dwarfs, on the other hand, may be either the representatives of a diminutive race, or the final terms of a degraded series, subject to harder and harder conditions. It is the average-sized species that are most likely to break out into new forms and to start a new series. I mention this with particular reference to *Ammonites planorbis* now known as *Psiloceras*, which is considered by Hyatt to be the ancestor of the whole family of the *Arietidæ*, and which he figures as of small size. The fry are abundant, but the race was really gigantic, as may be seen by the specimen over 3 ft. in diameter in the British Museum. Another point with regard to size has relation to the extinction of types. Hyatt looks for extinction only in the supervention of senile characters, and tells us to look in each case for a retrogressive series; but, to judge by examples from all parts of the animal kingdom, a gigantic size is of itself a cause of extinction from the increasing difficulty of sustenance, and it is often accompanied by specialization rather than by degeneration. We cannot call the elephant or the iguanodon degraded types. Thus types may perish at their acme, as I believe has been the case with some of the *Orthocerata* of the Carboniferous, with the *Arcestes* of the Trias, the *Ancyloceras* of the Neocomian, and the giant Ammonites of the *Lewesiensis* type in the Chalk.

How are we to tell whether an Ammonite has attained its full size? In some, it is indicated by its becoming senile, as shown by the loss of ornaments; in others, by the development of new, and usually somewhat irregular, forms of whorl, as in the Neocomian *Ancyloceras*, or in the *Phylloceras* of the Lias, and *Arcestes* of the Trias. Again, without saying that every full grown Cephalopod has the same number of septa, when they are far apart we may look upon the growth as still vigorous, and the animal destined to attain a larger size (and certainly the giant *Orthocerata* seldom have approximate septa), while an abnormal approximation indicates usually that the last septum has been reached.

We now have left for our main consideration the two great groups of characters, which have divided between them the affections of systematists—the ornaments and the sutures. To show the different estimates of the importance of distinctive characters that are held by different writers, and the confusion that thence arises in the mind of the student, it will be well to compare the figures given by Buckman (Pal. Soc., Mon. Ammonites Inf. Ool.) of *Grammoceras aalense* (Pl. xxxi, 15, xxxii. 6) and *Dumortieria striatulo-costata* (Pl. xl, 10, 11, 12), which shells are placed in different genera, with those given by Futtlerer of *Cycloceras binotatum* and *C. Flandrini* (Tab. xi, 34, and xii, 6, 7), which are placed in the same genus—the two species in both cases coming from the same beds. It seems to me that most observers would place the former two not only in the same genus, but almost in the same species, and the latter two not only in distinct genera, but in distinct families. Perhaps they might be wrong, but it is difficult from these examples to discover any "accepted" principles of Ammonite classification.

3. The Ornaments. One of the most remarkable points about the ornaments is their habit of undergoing change during the growth of the shell—those of the earlier whorls being different from those of the later. This change is taken, as explained last year, as a guide to the course the development has followed. We may conceive that at any one of the stages special peculiarities may be developed, which do not succeed in so deeply fixing themselves in the organization of the animal as to be carried on to the next member of the series; and in the necessary abbreviation of development in the later members, it is possible to speculate as to which of the stages will be crowded out. These possibilities open out a wide field for arbitrary assumption. When to this we add that Ammonites are supposed (without much reason that I can see) to progress and retrograde alternately and irregularly, it will be seen that there is very little limit to the number of genealogies an Ammonite may possess which happens to attract the attention of various writers. An example will illustrate this. According to Buckman, *Levesquei* is derived from *polymorphus* and leads on to *radians*, but according to Haug it is derived from *binotatum*; while *binotatum* according to Futtlerer leads to *insigne*, which has a separate origin according to Haug. Whatever, however, may be the later changes, it is obvious that the primitive form must be more simple than the later ones, and, unless the latter have some strongly marked feature, the young shell will naturally commence with being smooth and evolute. It seems, therefore, to be an entirely gratuitous assumption to suppose, with Hyatt, a constant line of simple radicals from which new stocks arise from time to time. It is like supposing a toothless progenitor for man, or a blind one for dogs.

This mistaking of mere negative embryonic characters, for indications of origin has far-spreading and, to my mind, disastrous results. It leads to the drawing out of long parallel lines of forms showing a theoretical development in one direction, totally regardless of any stratigraphical evidence, the corresponding series being connected only by being descendants from the same wretched little characterless form, incapable of contradicting any theory that may be made about it. Even the very evidence which has led to the acceptance of the doctrine of evolution we are thus bidden to ignore—the similarity between the various forms, which has convinced us that they cannot be disconnected genetically, we are told is mere "homoplasy," the exhibition of "morphological equivalence," and they have no genetic connection except by way of some *Ammonites miserabilis*, as one of these supposed ancestors is appropriately called.[8]

It must be admitted, of course, that very fundamental principles are involved in the way of looking at this matter, which are very well put by Haug in his monograph on the *Harpocerata*. As he points out, we cannot restrict this doctrine of morphological equivalence to Ammonites, and he calls to mind how some have traced the various groups of Gasteropods to corresponding groups of worms; how others have considered the subdivisions of birds as derived from different divisions of reptiles, and others again the horses of the old and new world as polyphyletic in origin. Nor can we stop there: if this be the case, we can no longer have any confidence in calling the negro our black brother: he may only be our millionth cousin through some arboreal ape, or possibly through some common ancestor still more remote among the worms. If this principle be accepted we must also give up all conclusions on the changes of physical geography indicated by the similarity of faunas and floras unless the similar forms are in the direct genetic line.

Of course the term "homoplasy" as used by Hyatt, is a misnomer: that word amongst biologists signifies the superficial resemblance of non-homologous organs, whereas the ornaments of Ammonites are strictly homologous; and the admitted occurrence of the true homoplasy in no way aids the acceptance of the doctrine of the polyphyletic origin of homologous organs.

If, however, we should ever come to admit such a polyphylogeny as a law of nature, it would immediately become a question whether morphological equivalence was not of much greater importance than genetic connection; whether, in fact, the bond of community of structure was not far closer than descent from an unlike ancestor. Are we justified in taking Ammonites as a group at all, if they be descended from different species of Goniatites.

It appears to me however, that the facts admit of a much more rational explanation by the monophylogeny of types, their rapid dispersal and migration, and their interaction whether by breeding or otherwise when brought into the same region. In some cases where a polyphyletic origin has been asserted, it is possible to account for the facts in a more simple way. To take the example that has been most fully worked out: Hyatt derives *Arietites* and *Schlotheimia* from different varieties of *Psiloceras*, and places *Oxynoticeras* as a senile modification of the former. Thus the whole of this group is supposed to arise along different lines from the simple form in the lowest beds, and the different branches are not in any way connected beyond the second stage. If, however, we examine the Triassic types of *Trachyostraca*, we find that these forms are already differentiated, and we have only

8 See Hyatt, "Evolution of Arietidæ," Smithsonian Cont. to Knowledge, 1889.

to suppose their arrival at different epochs into the Liassic seas to account for their order of appearance. To show this we have only to compare the following:—*Celtites epolensis*, Mojs. (Pl. ii, fig. 10) with *Psiloceras tortile* (D'Orbigny, Paléontologie Française, Terrain jurassique, Pl. xlix); *Sibirites Eichwaldi*, Mojs. (Pl. ii, fig. 11) with *Ammonites angulatus thalassicus* (Quenst. Ammoniten, Tab. ii, fig. 9), *Balatonites prezzanus*, Mojs. (Pl. ii, fig. 12) with *Am. Kridion*, Hehl, or *Am. Bodleyi* (Hyatt, Arietidæ, Pl. ii, fig. 24) or *Meekoceras cadoricum*, Mojs. (Ceph. Med. Triasp., Tab. xii, fig. 9) with *Am. oxynotus* (Quenstedt, Ammoniten, Tab. xxii, fig 29), the last being a somewhat doubtful comparison. All the earlier forms have their sutures less developed, but the general outline of them is such that a little more complication would produce those of the later.

Again there are cases in which a new type has arisen, not from a simple uncharacterized form, but from a previously existing type of another character. A good example of this appears in the description by M. Vacek, of the Ammonites of the Oolite at Cap S. Vigilio, (*op. cit.*) By comparing the figures taken from this work we seem to see how the *Stephanocerata* (Pl. i, fig. 11) may have arisen from *Hammatoceras* (Pl. i, fig. 10); and by comparing this with Pl. ix, fig. 1, of Vacek's work, almost from *Harpoceras*. In another direction we can pass towards *Perisphinctes* (Pl. i, fig. 13) and in a third towards *Aspidoceras* (Pl. i, fig. 12), and there is little to distinguish them in the outlines. It is not suggested that one of these gave rise directly to the others, but that some more elastic type originated a whole series having this apparent range of forms. Seeing that we thus pass from family to family Vacek remarks that these families do not seem to have any genealogical basis, as usually supposed.

I would now draw attention to a remarkable phenomenon, the bearing of which I will afterwards discuss, *viz.*, the recurrence of similar types (the sutures alone excepted) at different epochs. The most remarkable of these is the parallelism of Triassic and Cretaceous forms, particularly in Southern Europe. This will be best seen by putting the corresponding species side by side (see Pl. ii, figs. 1-9). Thus *Am. varians* of the Chalk (fig. 1) is well matched by *Ceratites felsö-örsensis* (figs. 2, 3) of the Trias; *Am. polyopsis* (fig 4) by *Carnites floridus* (fig. 5); *Am. navicularis* (fig. 6) by *Acrochordiceras Fischeri* (fig. 7); and *Am. coesfeldensis* (fig. 8) by *Trachyceras Reitzii* (fig. 9). So, too, it will be found that *Am. gosauicus* of the Cretaceous (Hauer, Cephalopoden der Gosauschichten,[9] Tab. ii) corresponds to *Balatonicus gemmatus* (Mojs. *l.c.* Tab. vi, fig. 3); *Am. laticlavius* (Sharpe, Chalk Ceph.[10] Pl. xiv, fig. 1) to *Trachyceras Curionii* (Mojs. *l.c.* Tab. xiv, fig. 4), as well as many others in which the resemblance is

9 Beiträge zur Paläontographie von Osterreich. Bd. 1. Vienna and Olmutz, 1858.
10 Palæontographical Society, 1853.

less close, but in the bulk extremely remarkable. So, too, if we examine the plates of a comprehensive work like that of Quenstedt on Ammonites, we find remarkable repetitions. There is very little to choose between the figures of *pettos* and *coronatus* (see Pl. i, figs. 6, 8), though these are placed in different families by Hyatt, nor between these and *crenatus* as given by Quenstedt (see Pl. i, fig. 9) and *fonticulus* (Pl. i, fig. 7)—all derived from widely separated horizons. A similar example is that of *Am. concavus*, which has been identified by different authors, sometimes with a shell from the base of the Upper Lias, sometimes with one from a central zone of the Inferior Oolite, as the two species which occur in those horizons can scarcely be distinguished. These forms are so connected in time that throughout the entire Jura, one of the group with flexuous ribs is followed by one of the coronate group.

There are other curious facts of the same description. Thus the Arietitic form dies out in the Lower Lias, till it is revived in the Upper Chalk in *A. tricarinatus*, *A. tridorsatus* and *A. margæ*.[11] The depressed exterior between two rows of knobs, as in *Trachyceras*, &c., disappears with *Schlotheimia* at the bottom of the Lias till it is renewed in a modified form in the Oxfordian in *bimammatus*, and becomes characteristic again in the Cretaceous *Hoplites*. At the same time the planulate and coronate types come to their maximum in the Jura, so that in the Upper Jura scarcely a keel of any sort is to be found.

How are we to account for these phenomena? The recurrence of Triassic types in the Cretaceous might be called an example of senile reversion. In that case, however, we must remember that the latter are stouter and have more complex sutures. Moreover the forms are not feeble characterless ones, but full of youthful vigour. The main question, however, is how we are to connect the two: are we to draw a line across the ages as though their representatives had been living somewhere on the quiet all the time, which is something like what Steinman does when he connects *Schloenbachia* with *Amaltheus*, with only a small branch—*Cardioceras*—as a connecting link between them; or are we to suppose a line of primitive radicals, without any characters of their own, but capable of starting either new or old types of form according to their surroundings, as Hyatt would appear to do; or are we to conceive of one type changing into another directly, and doing so again and again? It is because I cannot as yet give any definite answer to this question that I have said my remarks can only be desultory.

4. THE SUTURES. What relation the pattern of the sutures may have to the organization of the animal it is not easy to say. As I have many years ago pointed out, the fact of the septa being convex forwards, both in the centre and in the lobes of the

11 Schlüter, Beitrag zur Kentniss der jüngsten Ammoneen Norddeutschlands, Tab. v.

saddles, proves that there was a *vis a tergo* in the form of gas, pushing the animal forwards; and the apices of the lobes and their branches are the points of attachment of the mantle surface to the shell, by which it was held there till it was time to move. Hence the branching of the lobes are the real organic peculiarities, the shape of the saddles depending on the greater or less separation of these. In most cases the shell of the Ammonite was so thin that the pattern of the outside was reproduced on the inside, only in cases of very sharp keels or spines was the process cut off by a special shell deposit. Hence the disposition of these lobes is affected by the ornaments of the shell, and their general build has inevitably to be related to the shape.

Their ultimate form may therefore depend on two causes—first, the internal organization of the animal resulting from its law of progress independent of the immediate surroundings, but dependent on its history; and secondly their adaption to the shape and ornaments, which may change according to different laws—and it is easy to see by an examination of specimens that both these causes operate: on the one hand we can point to many instances in which the form of the sutures follows the shape of the shell, and on the other we can find numerous examples of shells with practically identical shapes which have very distinct sutures. It is only in the latter case that they can be taken as *independent* guides to affinity. And not only for this reason does their use in classification require the greatest care. It is well known that, as the animal grows, the sutures increase in complexity, so that if we compare the adult of one with a younger specimen of another they may seem much more distinct than they really are. It will thus be seen that the sutures present so many points of comparison that it is easy to discover resemblances and overlook differences or *vice versâ*, in accordance with one's theories.

If it is difficult to come to any general conclusions with regard to the ornaments, it is still more so with regard to the sutures. I do not refer to the minute differences in sutures of similar form, which are taken to distinguish the supposed series of genetically-connected mutations within the limits of a small family, but to the wider differences which *may* characterize larger groups. In the first place the broad distinction between ceratitic and ammonitic sutures has been shown to be of comparatively little significance: the non-crenated saddles are not universal even among Ceratites themselves, though from other points of view the type is constant in the genus; nor are such sutures confined to that genus, but are even better shown in some of the Dinarites. Branco has also shown (*l.c.*) that in the development of the sutures it is by no means universal that a ceratitic stage is passed through, as the digitations sometimes commence first on the saddles. This form of suture is, therefore, no more than a special variety. This is confirmed by the occurrence of such forms as

Buchiceras in Cretaceous times. Amongst Triassic Ammonites it is possible to separate out three distinct types which may be called respectively the *serial*, the *centro-serial* and the *normal* (fig. 1). The last (fig. 1, D), being almost universal amongst Jurassic and Cretaceous Ammonites, has imposed its nomenclature on the others; and all besides the "siphonal" and "superior" and "inferior lateral" lobes are denominated "adventitious" and "auxiliary" lobes. Hence it has been necessary for Mojsisovics, in studying the Triassic forms, to resort to an arbitrary definition of lateral lobes as those beyond the projection of the previous whorl—a definition obviously inapplicable when we have to deal with evolute forms.

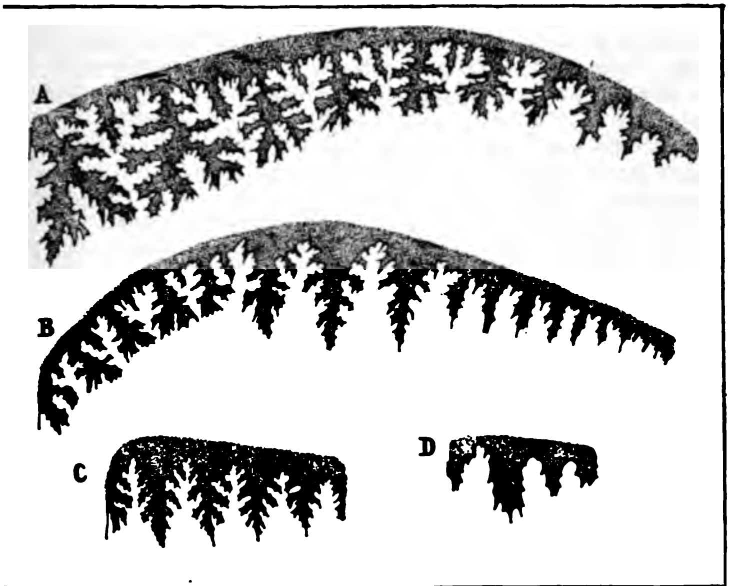


FIG. 1.—A. Serial suture of *Arcestes cymbiformis*.
B. Centro-serial suture of *Pinacoceras subparma*.
C. Serial suture of *Arcestes pseudogaleatus*.
D. Normal suture of *Trachyceras archelaus*.

The size of the lobes and saddles must necessarily be related to that of the shell, and as the outside of the whorl is larger than the inside (measured along the radius) the exterior lobes are naturally larger than the interior, and any deviation from their gradual decrease towards the inside is a specialization. The type of sutures which I call *serial* (fig. 1, A, C.) shows little or no specialization in this sense. It is best seen in *Arcestes* and its allies, called *Leiostraca* by Mojsisovics. *Arcestes* itself dies out with the Trias, but *Phylloceras* is continued through the Jura and Cretaceous, and always shows more uniform lobes than other genera. In this case of serial sutures, there seems to be a definite relation to groups of forms, all of which are more or less involute, inflated in cross section, and liable to have constrictions crossing the shell. In the last case the sutures have a definite relation to the constrictions, the summits of the saddles running parallel to them.

The *centro-serial* type of sutures (fig. 1, B.) is a very remarkable one. The series is always a long one, and two or three of the central members are of larger size and special character. These are best seen in the Triassic *Pinacoceras* (fig. 1, B), some species of which show the greatest complication of a particular kind that Ammonites ever attain to at any period of their existence. We can trace this kind of suture from the Devonian amongst the Goniatites, the last of which in the Trias is *Sageceras*. In later periods it is never seen to perfection, but some approach to it is sometimes made. This type is also characteristic of broad involute whorls, but depressed in cross section; but is not merely a result of this form, as there are numerous examples of similar shapes with quite distinct forms of suture; nor in this case is there any evidence that this form of whorl is a senile modification. But these types of suture belong to shells with little or no ornament, and are best developed in involute forms. The more evolute members of the same smooth group and even some of the involute, show an approach to the normal type, by the special enlargement of one or both of the two outer lobes. These may be called *serio-normal*, as in *Gymnites*. The importance, however, of the other lobes in these, and their general complexity, show their relation to the former, and certainly their distinctness from all members of the rough-shelled group or *Trachyostraca*. The later Ammonites of the Lias, on the contrary, have sutures which can easily be developed from the simpler forms of suture among the Trachyostraca. For this reason it is impossible to agree with Hyatt in deriving Lias Ammonites from *Gymnites incultus*, whose sutures are serio-normal and highly developed.

It would seem, in fact, that in Triassic times the course of Ammonite development parted into two directions. In the one direction the shell remained simple, and though the involution varied greatly, the curvature remained small, and the development was concentrated in the sutures. In the other direction the sutures remained simple, while the curvature increased, and the development took place in the narrowing of the whorls, and in the ornamentation of their surfaces. The latter branch has proved to have the greater vitality, and is the source of the remarkable Ammonites of later times. I thus agree with Mojsisovics (*l.c.*), on the ground of the sutures, in tracing Liassic Ammonites to the Trachyostraca, as I have already done on the ground of their ornaments and general build. If this be their true source the theory of a line of simple radicals falls to the ground.

In speaking of the complexity of the sutures amongst the Leiostraca, it is important to call attention to the particular kind of complexity. Complexity of sutures may mean either the complex branching of comparatively few lobes, or the multiplication of lobes with comparatively simple digitations of the sides. Amongst the Leiostraca, it is the latter form of complexity that occurs : the sutures may be many-lobed, and even deeply incised, but only very occasionally do they become compound, by the bifurcation of their saddles. Amongst the successors of the Trachyostraca the complexity of individual lobes is greatest, but in the Triassic forms the lobes are both simple and few, and their arrangement is of the "normal" type.

Amongst the almost infinite variety of form of normal sutures it is extremely difficult, and in our present state of knowledge probably impossible, to lay down any general laws. The pattern appears to be in many cases strictly dependent on the form of the shell, so that given the sutures one can sometimes predicate the shape and ornaments of the shell, but the cases in which we cannot are much more numerous, and it is still harder to predict the sutures from the shell. Examples in which the sutures appear to be directly dependent upon the external features may be noted.

In general, if the exterior is keeled or marked in any way by a central line, the siphonal lobes tend to be parallel; if the exterior is broad, they tend to diverge.

A peculiar form appears to accompany the straight ribbed *Arietites*: the outer saddle is divided by a lobe so that the *outer* half is the largest, and the inner saddle is either larger or longer than the outer (*cf.* D'Orb. Terr. Jur. Pl. xlvi.). A contrary form accompanies falcate ribs, *i.e.* is characteristic of the *Harpoceratidæ*: the outer saddle is divided into two parts, so that the *inner* half is the larger, and the outer half tends to become almost separate, so as to look like an additional saddle in the siphonal lobe, which might be called a parasiphonal saddle (*cf.* D'Orb. Terr. Jur. Pl. lv.). This form of suture is seen even in the falciferous Ammonites of the Cretaceous, which can scarcely perhaps, be genetically connected with *Harpoceras*, and are certainly placed in a distinct genus.

What may be called the broad "palmate" type of lobes, particularly the outer, is markedly shown in *Lytoceras*, which thus seems to me not very closely allied to *Phylloceras*, as it is usually considered, but to be rather a descendant of the Trachyostraca. The same type, however, is less well seen in Ammonites with two spines, such as *Birchii* and *Henleyi*. Whether this is any indication of genetic connection appears to be quite an open question.

Another peculiar form of saddle which may be called "protense," is found in forms which have bands across the whorls, either as constrictions or elevations. The saddle seems pulled out and is Y shaped (*cf.* D'Orb. Terr. Jur. Pl. cxcvii.). These, however, approach the "serial" type, and may belong to the Leiostracan group (*cf.* D'Orb. Terr. Jur. Pl. clxxxix.).

As an example of the non-dependence of sutures upon form, when the species are widely separate in time, may be cited those of *Am. achilles* (D'Orb. Terr. Jur. Pl. ccvi.)[12], which are the most complex of all, and have in a high degree the sloping position on the inner side which is called "dependent"; yet, the form which most nearly approaches it in the Lias, *Am. communis*, has simple and non-dependent sutures. It is easy to say that they belong to different genetic stocks: the question is, why has the external form come back again to its old characters?

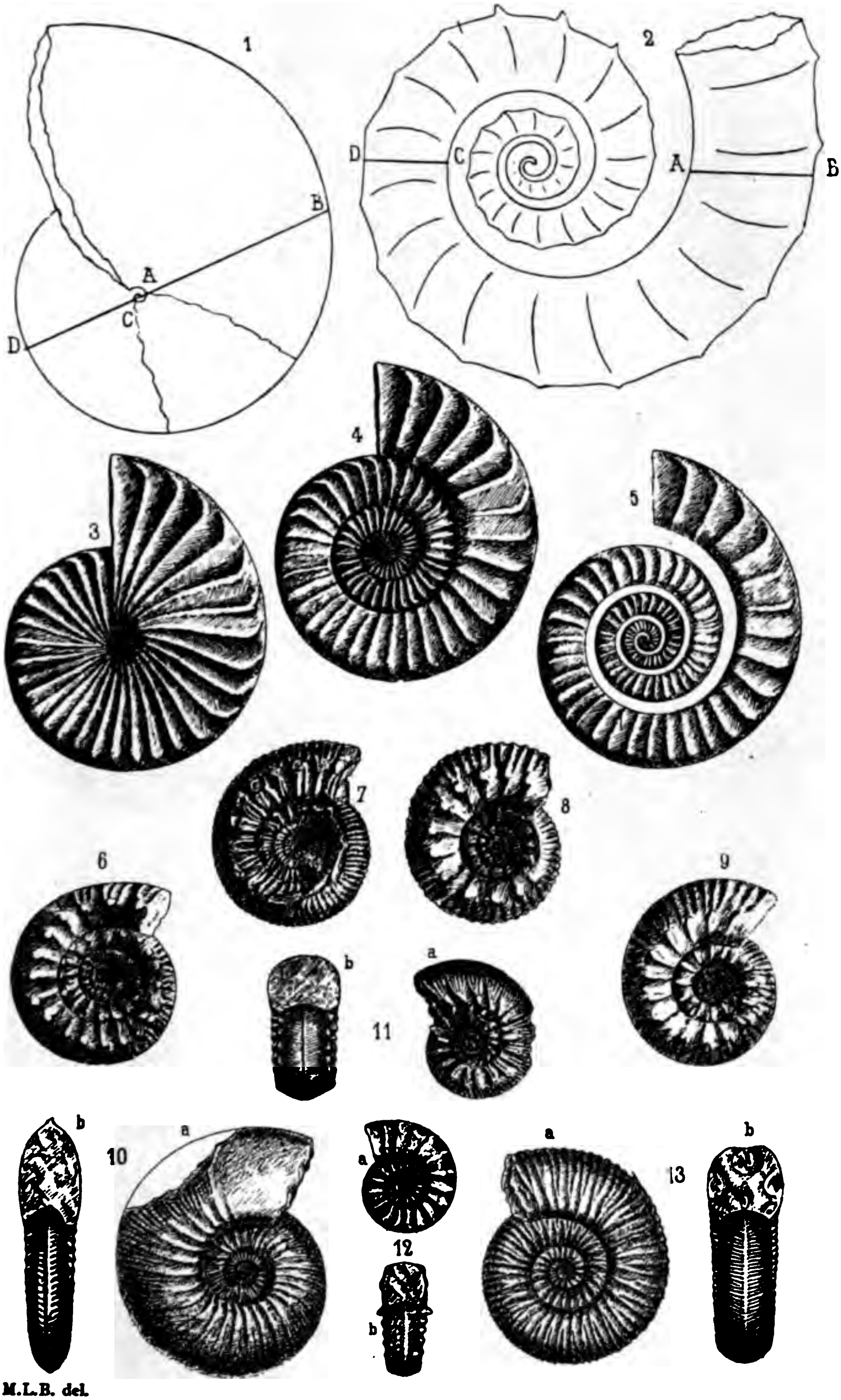
On the other hand, there is a great similarity in the general form of the sutures between *Am. raricostatus* (D'Orb. Terr. Jur. Pl. liv.) and *Am. lamellosus* (D'Orb. Terr. Jur. Pl. lxxxiv.) which belong to two different groups.

Similar observations might be multiplied; and they serve on the one hand to show the difficulty of obtaining any general laws, and on the other to hold out hope that such may some day be discovered. As to the modern genera of Ammonites that are supposed to have a bond of union in the sutures, they go but little way towards the solution of the problem in hand, for they do not range much beyond the ancient idea of species. Hence having found the sutures of any given example of such a "genus-species," we can expect the same in the other members of the same "species-genus." But when we leave the period, and except in the case of the wider-spread species, even the locality of these minor groups, the threads which serve as a clue become so numerous and tangled together that we easily get lost.

In concluding this address I am more than ever conscious how little of a conclusion it really presents. In the study of Ammonites, as in the climbing of a mountain, each step in the ascent only reveals further heights to be surmounted; and though the sweet plains of genealogical speculation stand invitingly before us with their numerous interlacing paths, and shady labyrinths, if we want to know the history of Ammonites as a whole, we must be cautious of their allurements, lest they lead us up and down in no particular direction, and leave us pretty much where they found us.

It is my conviction that in spite of the large quantity of material that has been collected, we still want much more information about the fossils, and their range in space and time, before we are in a position to lay the outlines of their true history, and this information will come, not altogether by

12 D'Orbigny's *Paléontologie Française* is quoted throughout as being most easily accessible.



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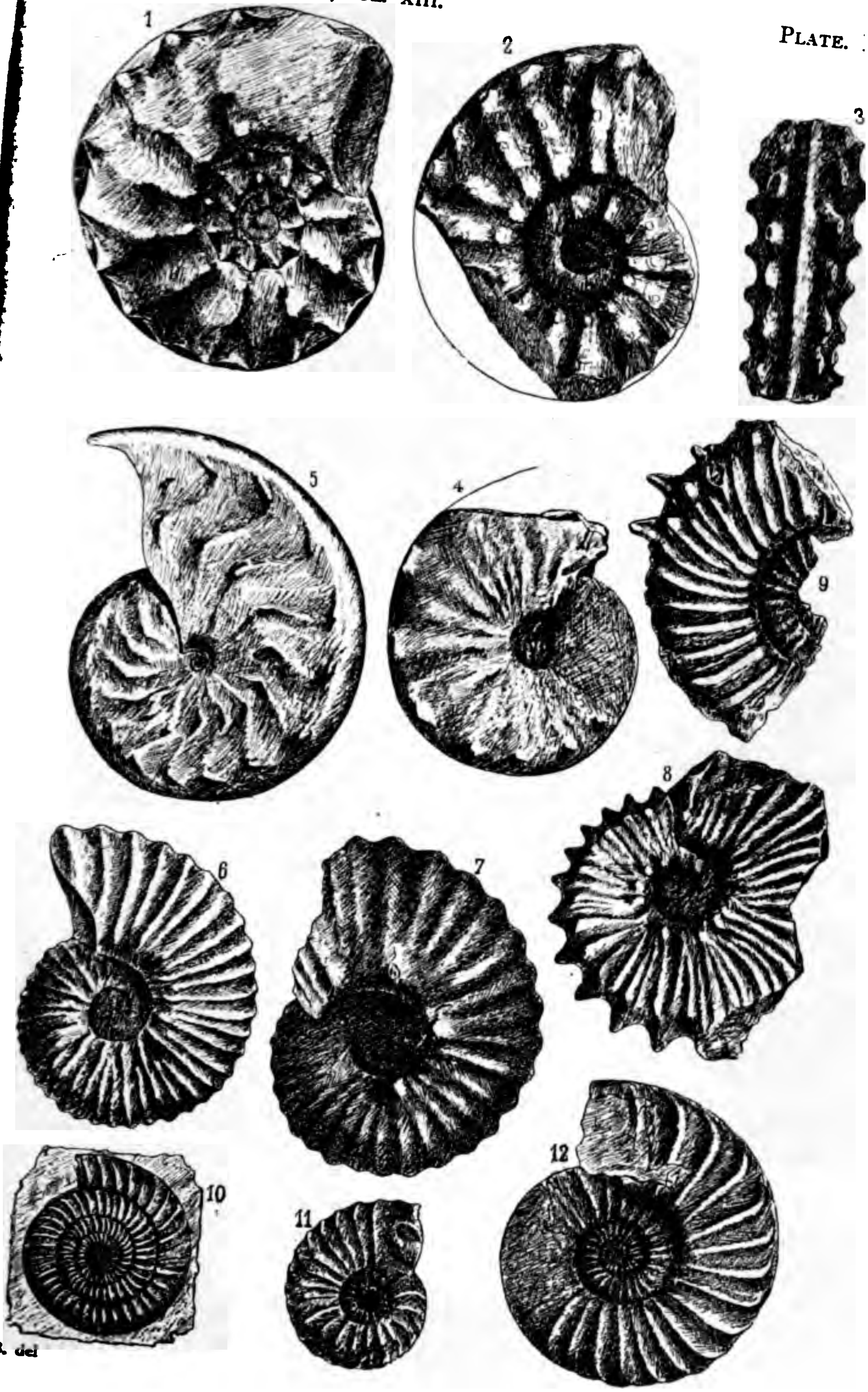

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discovering more so-called new species, but by comparing the material already in hand, guided by the principles of evolution, but guarded against the trammels of any one particular theory.

EXPLANATION OF THE PLATES.

PLATE I.

FIG. 1. *Am. Largillierlianus*, from D'Orbigny, Terrain crétacé, Tab. xcv.
„ 2. *Crioceras Duvalii*, from D'Orbigny, *l.c.*, Tab. cxiii.
These two figures illustrate the method of measuring the curvature in Ammonites by the inverse ratio of AB : CD. The latter of the above species has more curvature than the former.
FIGS. 3–5. An imaginary Ammonite ("*Am. transmogrificabilis*"), to illustrate the effect of involution alone. All three have the same external curve, *i.e.*, the same curvature, and differ merely in the breadth of the whorl.
FIG. 6. *Am. pettos*, Middle Lias, from Quenstedt, Die Ammoniten, vol. i, Tab. xxxiv, fig. 23.
FIG. 7. *Am. fonticulus*, Upper Lias. Original.
„ 8. *Am. coronatus*, Lower Oolite, from Quenstedt, *l.c.*, vol. ii, Tab. lxvii, fig. 8.
FIG. 9. *Am.* "*crenatus*," Middle Oolite, from Quenstedt, *l.c.*, vol. iii, Tab. xciv, fig. 26.
These figures illustrate the recurrence of similar forms of Ammonites at different periods.
FIG. 10. *Hammatoceras tenuinsigne*, from Vacek, Fauna der Oolithe von Cap S. Vigilio, Tab. xii, fig. 7. (Abh. k.-k. geol. Reichs, Bd. xii, Wien, 1886.)
FIG. 11. *H. sagax*, from Vacek, *l.c.*, Tab. xv, fig. 15.
„ 12. *H. pugnax*, from Vacek, *l.c.*, Tab. xvi, fig. 1.
„ 13. *H. gonionotum*, from Vacek, *l.c.*, Tab. xvi, fig. 9.
These illustrate the connection of genera. The first is keeled and has the general build of the Harpocerata. The others only show signs of connection with this by the line down the centre of the siphonal side, and they show respectively the general characters of *Stephanoceras*, *Aspidoceras*, and *Perisphinctes*.

PLATE II.

FIG. 1. *Ammonites varians* from Sharpe, Chalk Cephalopoda (Pal. Soc.), Plate viii, fig. 4, to compare with
FIGS. 2 and 3. *Ceratites felsö-örsensis*, from Mojsisovics, Cephalopoden der Mediterranen Triasprovinz, Tab. xiii, fig. 1.
FIG. 4. *Ammonites polyopsis*, from Schlüter, Beitrag zur kentniss der jüngsten Ammoneen Norddeutschlands, Tab. iv. fig. 1, to compare with
FIG. 5. *Carnites floridus*, from Hauer, Cephalopoden des Muschelmarmors von Bleiberg in Kärnthen, Tab. i, fig. 12.
FIG. 6. *Ammonites navicularis*, from Sharpe, Chalk Ceph., Pl. xviii, fig. 3, to compare with
FIG. 7. *Acrochordiceras Fischeri*, from Mojs., *l.c.*, Tab. xxxiii, fig. 8.
„ 8. *Am. cæsfeldensis*, from Schlüter, *l.c.*, Tab. i. fig. 5, to compare with
„ 9. *Trachyceras Reitzii*, from Mojs., *l.c.*, Tab. vii, fig. 3.
The above illustrate the parallelism between many Cretaceous and Triassic Ammonites.
FIG. 10. *Celtites epolensis*, Mojs., *l.c.*, Tab. xxxviii, fig. 13, a supposed forerunner of *Psiloceras*.
FIG. 11. *Sibirites Eichwaldi*, Mojs., Arktische Triasfaunen, St. Petersburg, 1886, Tab. x, fig. 1–9, a supposed forerunner of *Schlotheimia*.
FIG. 12. *Balatonites prezzanus*, Mojs., Med. Triasp., Tab. xxxviii, fig. 4, a supposed forerunner of *Arietites*.

THE LANDSLIP AT SANDGATE.*

By W. TOPLEY, F.R.S.

[*Read Friday, 7th April, 1893.*]

THE coast of Kent, from Hythe to Abbotscliffe (halfway between Folkestone and Dover) has long been noted for landslips. Measured along the shore this is a distance of eight miles, and in this distance there is probably in all not more than one mile in which the beds along the sea front are normally in place. There has been a general slipping seawards over the various clays—Gault on the east of Folkestone; Sandgate Beds between Folkestone and Shorncliffe; Atherfield Clay to the west. The slips over the Atherfield Clay extend westwards along the Lower Greensand escarpment to Lymne. Here the old Roman fortress of Studfall Castle, built on the slope of the escarpment, has been destroyed by a landslip, the ruins being spread about on the irregular ground formed of Weald Clay. An interesting account was published of a slip near Lymne in 1725, which occurred during a very wet season. The side of the hill gave way, "raising by that means the flat at the bottom and letting the brow, with the farm house upon it, sink 40 or 50 feet at least. What is remarkable it sunk in one night, and so gently that the farmer's family were ignorant of it in the morning when they rose, and only discover'd it by the door-eaves, which were so jamm'd as not to admit the door to open." †

All the Atherfield Clay outcrop east of Lymne has slipped; some small slips took place near Hythe at the same time as the Sandgate landslip. Between Hythe and Shorncliffe the whole cliff has slipped; the Hythe Beds capped by Sandgate Beds are exposed in a quarry on the west of the Seabrook Valley, but much below their normal level, the whole line of cliff having slipped over the Atherfield Clay, whilst the Sandgate Beds have also slipped on themselves.

Passing by Sandgate for the present we may note some important slips on the west of Folkestone, one of which occurred in the early part of the last century and was described in the *Phil. Trans.*‡ The Folkestone Beds here form the upper part of the cliff; the Sandgate Beds the lower part; the Hythe Beds appearing on the foreshore. The cliff sank about 40 feet, and the

* This paper was illustrated by a series of lantern slides, kindly lent by Mr. R. Kerr F.G.S., of Folkestone.

† Rev. W. Gostling, Gentleman's Mag., vol. xxvi, p. 160, 1756. The letter was written in 1727. See also P. Collinson, Phil. Trans., vol. xxxv, p. 551, 1728. For description of other landslips in the Weald, along the Lower Greensand escarpment of Kent and the Upper Greensand escarpment of Hants, see "Geology of the Weald," pp. 316-319, 1875.

‡ Rev. J. Sackette, vol. xxvi, p. 469, 1716. E. King, vol. lxxvi, p. 224, 1786.

movement forced up the rocks on the shore, where they are now seen to have an abnormally high dip.

The most important landslip along this coast is that of the Warren, between Folkestone and Dover. The Gault of Copt Point dips gently toward the north-east, and passes under the Chalk along the foreshore. The exact line of outcrop cannot be accurately determined in consequence of the great amount of slipping. The Upper Greensand is here locally developed as a clayey sand, and this may aid the slips by holding some water. The Warren extends from the mouth of the Martello Tunnel to Abbotscliffe, a distance of $1\frac{5}{8}$ miles, and has an average width of about $\frac{1}{4}$ mile. The whole of this is a slipped and tumbled mass of Chalk.

In February, 1877, some serious slips occurred here. The first was at the east end of the Martello Tunnel, where an area of about 100 acres slipped along and over the railway. The cutting, 100 feet deep, was filled with fallen chalk for a length of about 200 yards. The pressure of this movement forced up the Gault on the beach in mounds 6 or 7 feet high.

Two days afterwards another serious slip occurred at the east end of the Warren, where the line was again blocked. These slips followed heavy rains in January, the rainfall being about double the average. Similar falls occurred about the same time at the Undercliff in the Isle of Wight.

In March, 1881, another slip occurred in the Warren.

Mr. Price* has recorded a slip which took place at the west end of the Warren in January, 1886. The area affected was about one mile in length, and the beds were forced up all along the shore opposite the slip: near the east end of the slip the Chalk was forced up nearly 20 feet, and at one place the Gault was raised into hillocks several feet high. This was a very wet month, the rainfall in East Kent being more than in any year since 1877.

In order to render the Warren less insecure, the S.-E. Railway has under-drained it. Galleries are driven in from the sea, and a horizontal tunnel is carried under the landward side of the undercliff. A large quantity of water finds its way into these galleries, discharging direct into the sea.

In November, 1892, a slip in the Gault occurred near the Warren Inn, which carried the roadway down about 40 feet.

In December, 1839, at about the same time as the great landslip at Lyme Regis, there was a slip at the Warren.

We may now return to Sandgate and consider the geological conditions which have determined the recent landslip there.

The Sandgate Beds consist of various beds of clayey sand, some more clayey than others, but probably not any of it is a completely retentive clay. This series may be about 80 feet in

* Geol. Mag, 1886, p. 240.

SECTIONS ILLUSTRATING THE GEOLOGY OF HYTHE AND FOLKESTONE.

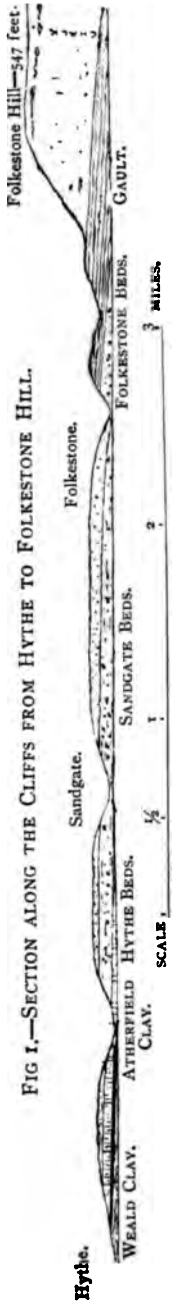
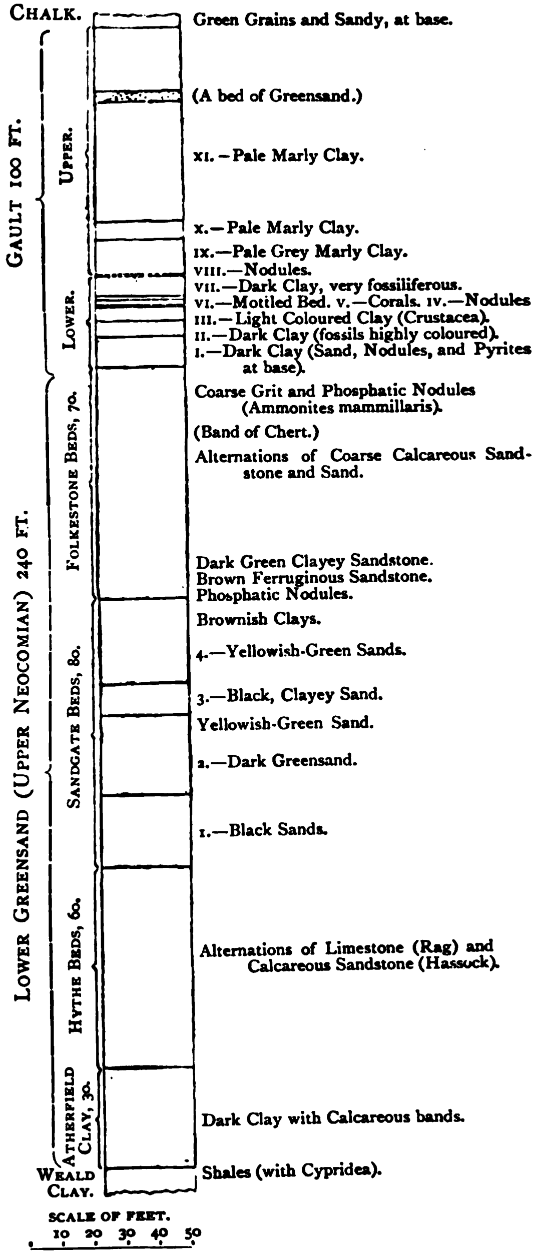


Fig 1.—Section along the Cliffs from Hythe to Folkestone Hill.

Fig. 2.—Vertical Section of Beds.



thickness; the beds can best be seen under the cliff on the west of Folkestone and again in the cuttings and quarries west of Sandgate. At Sandgate itself there are but few exposures and none in an undisturbed condition, as the whole of the sea-front here is a landslip.*

The Hythe Beds are seen on the shore east of Sandgate with a dip to the N.N.E., and again opposite the middle of Sandgate with a dip in the same direction, but when last seen on the east of Sandgate the strike is turning round to about E. and W., and a very slight change of dip would carry the beds below sea-level in front of the eastern half of Sandgate, where no rocks occur down to low water mark.

The Hythe Beds rise above the shore at the western end of Sandgate, and were formerly quarried there, Wellington Terrace being built on an old quarry. But the beds are not now seen, except on the shore, being everywhere covered by the fallen masses of Sandgate Beds.

In nearly all exposures on the shore, the rocks have an abnormally high dip, often from 20° to 30°, and in places as much as 50° to 60°. These dips are probably due to old slips, the pressure of the moving mass of land forcing up the rocks along the shore. Similar high dips are constantly seen in front of landslips.

A band of clay is seen on the shore, with the Hythe Beds dipping apparently over and under it. This strongly resembles Atherfield Clay, especially in the brown colour of its more weathered parts: it seems to be a stiffer clay than any in the Sandgate series; but how it comes in that position is not clear. It may be due to movements of the rocks caused by old landslips, or it may be due to a strike-fault. This clay is not noted on the Survey Map; at the time when this area was surveyed the shore was much more extensively covered with shingle than now, and the clay was probably rarely exposed.†

There is a disturbance in the Hythe Beds at Horne Street, in the Seabrook Valley, which strikes S. 32° E. If this is a fault, and not a mere local disturbance of the Kentish Rag, it may range towards the clay-bed on the shore.

With this exception I do not see that the Survey Map, constructed by Mr. F. Drew (and published in 1863), needs correction, nor can I see any evidence for the faults suggested by Prof. Blake in his recent papers on Sandgate.‡

The groyne south-west of the hospital is entirely built on clay;

* The details of the vertical section, Fig. 2, p. 42, are from Mr. Price's paper, *Proc. Geol. Assoc.*, vol. iv, p. 135 (1875).

† The clay was not seen by Fitton, who describes the beds along the cliffs and shore in great detail; but in a footnote (p 124) he says, from information supplied to him, that the clay was exposed in 1833: "It is very marly, and includes a great quantity of wood and pyrites, and in places resembles the Gault of Eastware Bay."

‡ Nature, March 16th; The Surveyor, March 30th, 1893.

this is no doubt the Atherfield Clay, in its normal position below the Hythe Beds.

The higher part of the cliffs behind Sandgate are composed of Folkestone Beds; the junction of the two sets of strata, Folkestone Beds on Sandgate Beds, can be traced round the Enbrook Valley without a break; there is no evidence here of a fault. The whole town of Sandgate is built on a tumbled mass of Sandgate Beds, formed by a series of landslips. The evidence of this was well seen, during March of this year, in a deep cutting for a sewer. Under 8 feet of greenish Sandgate Beds there was a mass of peaty stuff with roots and leaves of recent plants. Many of the houses built on the hill have had to be taken down because of the slow movements of the ground. The eastern half of the area was deeply drained about 40 years back to intercept the underground water, and to render the ground less insecure. This drain passes under the area known as the Undercliff, and ends in the west, just at the east end of Encombe Grounds, exactly where the recent slip commences. The land about the Undercliff was very wet and boggy; but the drain referred to greatly improved it, and this part of the town has of late years shown no signs of movement. There was a slip here in the year 1827.

From the east end of Encombe Grounds the recent slip extended westwards to the Military Hospital. Here a deep cutting for a sewer was made many years back, which has no doubt given a free passage for surface water. To the west of the sewer the land is Government property, and this has been properly drained. Between the Hospital and the east end of Encombe Grounds the land has not been drained, and it is only within this undrained area that the recent slip took place.

The recent slip extended for a length of about 920 yards; it had a maximum breadth of about 233 yards measured from the back of Encombe Grounds to high-water mark; but the foreshore here was also moved for a breadth of about 100 yards.

The greatest vertical movement, at the western part of Encombe Grounds, seems to have been about 10 feet; but the total amount of various small slips at the east end of the grounds is perhaps almost as great. The horizontal movement is small; it may perhaps have amounted to a total of some few feet in parts of the Encombe Grounds, where many slips occur close together; but in the lower parts and along the sea-front it is much less.

The movement was very gentle. Greenhouses were wrecked; but most of the glass was unbroken. Several houses are badly shaken, but no dwelling-house fell. Some are more seriously impaired than appears from a casual inspection outside, the foundations having been greatly damaged.

Some interesting facts were observed where the slipped faces of clay were fresh; they were streaked with true slickensides running obliquely down the face. The eastmost end of the slip is a nearly straight line running S.E. from the east end of Encombe Grounds. There are always small slips at this end of the Grounds about this time of year. Some were noticed a few days before the big slip occurred.

There has been considerable movement on the shore. One wooden groyne, opposite Littlebourne Lodge, has been snapped across by the moving land, the lower part of the groyne having stood fast against the Hythe Beds, while the upper part was pushed slightly towards the west. The maximum movement seaward of the sea-wall is about opposite this groyne, at the most it does not exceed 18 inches. The groyne next to this on the east has apparently not moved, or if so it has moved bodily without displacement. The next groyne has been forced up about 4 feet in its lower part; and the same thing has happened to the sewer-outfall opposite Camp Road.

The band of clay opposite Gloucester Terrace and Wellington Terrace was forced up; the movement continuing during the Monday and perhaps later. Mr. R. M. Jenner, of Sandgate, who examined the shore at daybreak on Sunday morning, tells me that the whole of this clay was in motion, the blocks of stone lying on it being slowly lifted up and turned over.*

The groyne opposite the Coast Guard Station has been pushed up a little; some change also took place at the end of this groyne, for before the slip a boat could get round the end of the groyne at low water, which cannot be done now.

As a rule the houses built of wood have stood best; brick houses come next, but there are comparatively few of these. Stone houses as a rule have stood worst, but this is because they have been badly built, the stones being only roughly cemented and no attention having been paid to the binding. The front of Spring House is of brick; this has given way, bending over to the east, its weight being supported by Spring Cottage, which is built of wood. The back of Spring House is well constructed of stone; and this has scarcely moved.†

A new brick house, strongly built, stands on the site of the west end of Encombe House, which was taken down some years back. This new house is uninjured, there being only a few small cracks in its southern front and signs of a slight movement at its north-western corner, but the stable yard against the southern front is badly cracked, and the stables, only a few yards off, are much damaged.

I have already referred to the fact that the amount of shingle

* I am greatly indebted to Mr. Jenner, and to Mr. A. G. Sellon, of Sandgate, for much nformation about the landslip, and for other facts of interest relating to the district.

† For these facts I am indebted to the kindness of Mr. A. Bromley, Architect, of Folkestone, who has reported to the Local Board of Sandgate on the damage done to houses in the town.

in front of Sandgate is much less now than it was some years back. When the Ordnance Survey was made in 1871, the "High Water Mark of Ordinary Tides" was 45 feet from the sea-wall opposite the Coast Guard Station, and from 60 to 70 feet at the west end of the town. In consequence of extensive groyning to the west of Sandgate, the eastward travel of shingle was stopped and the sea-front of Sandgate became almost bare of shingle, the sea-wall was partly destroyed, and a small tract of land near the sluice of the Military Canal was washed away. The sea wall was repaired a few years back, and new groynes were made, the result being that the shingle is now again slowly accumulating.

The loss of shingle has no doubt rendered the land more insecure, there being less permanent weight on the foreshore. The recent slip commenced at about low spring tide on the evening of March 4th; the movement diminished as the tide rose, although not entirely ceasing, and at low tide next morning a second slip took place.*

The extensive slips at the Warren have no doubt been much aided by the absence of shingle; there used to be a continuous bank of shingle with a cart-road on it, from Folkestone to Dover. The harbour works and the jetty at Folkestone have arrested the shingle there, and the ground in front of the Warren is now practically bare of shingle. The sea undermines the cliff and thus aids the landslips. At Sandgate the sea-wall prevented any direct damage to the town from the want of shingle.

Much water drains away along the shore at low tides: this generally contains some fine sand washed out of the fallen Sandgate Beds behind the town. The constant loss of the sand must tend to make the ground more liable to slips.

Much has been said as to the damage which may have been done to the land by the blowing up of the *Calypso* (by dynamite) in June, 1891, and of the *Benvenue* (by nitro-glycerine, gunpowder, etc.) from September to December, 1892. The *Benvenue* was wrecked 450 yards from the sea-wall opposite Littlebourne Lodge, near Wellington Terrace; the *Calypso* was about half a mile from the shore opposite the Battery Steps, beyond the west end of the town. A pond east of the Encombe Grounds was suddenly drained at the time of the *Calypso* explosions: a crack opened at the bottom of the pond and fish there got away which were taken out of the crack lower down the hill. The cellar of Salem House, near the Convalescent Home, is said to have been thus flooded. A house in Gloucester Terrace is said to have cracked, and the roofs of other houses were damaged. These

* The Rev. E. Hill in his description of the Zug landslip, July 5th, 1887, attributes this in part to the unusually low level of the lake, *Rep. Brit. Assoc.*, for 1887, and *Geol. Mag.*, 1887, p. 473.

appear to be the only evidences of the effect of this explosion. The pond and Salem House are not within the area affected by the recent slip, but Gloucester Terrace is within it. The vibrations caused by the *Calypso* explosions are said to have been more felt than those of the *Benvenue* although much farther off and probably on Weald Clay. The *Benvenue* vibrations as felt at the Coast Guard Station were not greater than those caused by heavy gales at high spring tides. It is impossible to say that these explosions had no effect in rendering the ground more insecure; but sufficient other cause for the landslip can be found.

The rainfall of February was unusually heavy. Mr. Mackeson's rain-gauge at Hythe registered 4·3 inches in that month, 24 out of the 28 days being wet; 1·06 in. fell on one day (Feb. 21st). The average February rainfall for the ten years 1883–92 was 1·95 in., with 13·8 wet days.*

The whole evidence points to the fact that the slip was due to the great accumulation of water in the broken mass of Sandgate Beds caused by the excessive rainfall of the preceding month. The slipped area is not drained, whereas the districts immediately east and west of it are drained, and this renders them comparatively safe. Mr. Baldwin Latham, who is advising the Local Board on the subject, recommends a deep drain at the back of the landslip to catch all water coming from the Folkestone Beds of the hills behind. This is certainly the proper step to take, and it will no doubt render any such calamity as that now described very improbable in the future.

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* In Symons' "Monthly Meteorological Magazine" for March there is an account of "The Sandgate Disaster," giving the February rainfall for East Kent. The fall varied, at six stations from 3·06 to 4·3 in.; that at Hythe being the largest.

ON THE ORIGIN OF THE CRYSTALLINE SCHISTS,

With special reference to the Southern Highlands.

By GEORGE BARROW, F.G.S., of the Geological Survey of Great Britain.

[*Abstract of Lecture delivered Friday, March 3rd, 1893.*]

SIMPLY premising that a schist could be easily seen to possess a parallel structure, and to be completely crystalline, a series of slides was shown to illustrate the mode of occurrence of these two factors. A specimen of crushed Torridon Sandstone was exhibited, in which the parallel structure is shown by the "flaser" (flowing) crush-material and dirt that flows round the uncrushed portions of the original pebbles.

The first essential—parallel structure—is thus produced; but not the second, for the flaser material has not become completely crystalline. A crushed grit from the Southern Highlands, however, is shown to be a true schist, because the flaser material, in which lie the pebbles or remnants of pebbles, has completely crystallized and we thus have a schistose grit. Similarly a crushed gneiss shows fragments of the old rock round which flows a substance essentially composed of non-crystalline comminuted material. This is compared with the crushed granite of Ben Vuroch in which the recrystallized flaser material forms with the remnants of the felspar crystals (augen) a true augen-gneiss or schist. Evidence was next given to show that the crystallization was quite independent of the development of flaser structure.

A section of highly altered calcareous shale was shown on the screen, and it was seen to possess very perfect parallel banding and was also a completely crystalline rock. In the hand-specimen it somewhat resembles a hornfels, and would not be called a schist except after being examined under the microscope. A specimen of quartzite was shown to be entirely a crystalline rock and yet to possess no parallel banding. Thus the parallel banding or arrangement of the component minerals and the crystalline condition of the rock are two independent factors that are united in a true schist. A particular band of rock from the head of Glen Isla was then examined, and it was shown to be a fine-grained schist over a large area, but on approaching a mass of gneiss of igneous origin, the fine schists became coarser and contained crystals of Kyanite and Staurolite.

Detailed evidence was given to show that this phenomenon is repeated on a large scale in the Southern Highlands. This region has been invaded by a mass of muscovite-biotite-gneiss, mostly a deep-seated rock, but which manifests its underground presence by sending up coarse veins of Pegmatite. These Pegmatites have been traced to their true source owing to the appearance of considerable masses of the gneiss on the surface in north-east Forfarshire. In this district the gneiss is shown to have produced a profound metamorphism on the different members of the Highland series. Argillaceous rocks are altered to Staurolite-, Kyanite-, or Sillimanite-schist, and in most cases the minerals are arranged parallel to cleavage or movement-planes; thus showing that the crystalline schist results from the action of contact or thermo-metamorphism upon rocks already moved or crushed. Evidence had been adduced from the Galloway and Shap areas tending to the same conclusion.

Finally a short account was given of the pressing together of the rocks in deep folds ("packing"), in the areas that overlie reservoirs of igneous material. This packing increases the cover of higher rock and so has the effect of pushing the lower members of the series into a hotter region. To this depth of cover the greater effects of the intrusive rocks are ascribed.

Thus the schists result from the combined effects of earth movements and heat (dynamo-metamorphism and thermo-metamorphism) and the areas are large and the rocks more coarsely crystalline in proportion as the phenomena are produced at a greater depth below the surface.

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY.)

(Department of Botany.)

SATURDAY, 18th MARCH, 1893.

DEMONSTRATION ON GYMNOSPERMS BY W. CARRUTHERS, ESQ., LL.D., F.R.S.

Report by PROF. G. S. BOULGER, F.L.S., F.G.S.

(Revised by MR. CARRUTHERS.)

THE party having assembled in the Herbarium, Mr. Carruthers, the keeper of the Department, commenced his remarks by saying that the Gymnosperms were the lower group of flowering plants, the higher division being the Angiosperms, and that though Gymnosperms, owing to the similarity in the structure of their stems, were often classified as if their nearest affinity was with Dicotyledons, they were in fact lower than Monocotyledons, and had many points of affinity with the higher Cryptogamia. Turning to a diagram of the yew (*Taxus*), Mr. Carruthers then pointed out that the distinctive character of all Gymnosperms was that their ovules were not enclosed in an ovary, but had an open canal leading to a pollen-chamber and were thus fertilized directly without the intervention of a stigma. Gymnosperms are, it was pointed out, divided into three groups, the Cycads, the Conifers, and the Gnetaceæ. To the Conifers belong the yew, the juniper, and the Scots fir, the only species native to Britain, together with a large number of cultivated kinds. The fossil remains of Gymnosperms, as of other plants, are often but poorly preserved ; but the wood in this group can be easily recognised even in very small fragments. A transverse section of the wood of an angiosperm shows large holes, the sections of vessels ; but in that of gymnosperms all the cells are nearly uniform, though certain large openings, the resin-canals, may be mistaken for vessels. In a radial section, one, that is, parallel to the medullary rays, the cells are seen to be marked with discs which are in fact pits or pores; but, though the wood is recognisable as belonging to a gymnosperm, it tells us little more.

As to their occurrence as fossils, the oldest known with certainty are those found by Hugh Miller in the Old Red Sandstone ; for, though Sir William Dawson has described some from Cambrian and Silurian rocks, he has now modified his views as to their position. Our knowledge of the fossil plants of the Palæozoic rocks is largely due to Nicol, the inventor of the Nicol's prism ; for he it was who first cemented mineral bodies to glass with Canada balsam before grinding them down into transparent slices. In the Coal Measures there is an abundance and variety of gymnospermous fossils, many genera, represented by many species, being found. From their stems alone these resemble true conifers; but their fruits, which are more important as indicative of their relationships, are also present. Some of these, which were figured by Mr. Binney under the name *Trigonocarpon*, nearly resemble the maiden-hair tree of Japan (*Ginkgo biloba* or *Salisburia adiantifolia*), a member of the yew tribe or Taxineæ. M. Brongniart has figured many specimens of these fruits from the Coal Measures of France, some even showing pollen-grains in their pollen-chambers. The supposed cycad stems in Palæozoic rocks prove to be lycopodiaceous, no true Cycadeæ being known, whilst of the conifers the Taxineæ are apparently the most highly organised, the nearest to the Gnetaceæ, and it is this highest group that we find represented in the Palæozoic.

In the Permian, *Walchia*, and in the Triassic, *Voltzia* more nearly approach the true conifers; whilst in the Upper Trias, Lias, and Kimeridge Clay we have true pines, and the existing genus *Araucaria* is very characteristic of the Jurassic series. When we come to the Greensand we not only have the genus *Pinus* considered in a wide sense, but existing sub-divisions such as *Abies* and *Cedrus* are represented, whilst *Sequoia*, to which the Wellingtonia belongs, a genus now confined to a very limited area, was in Cretaceous times widely distributed. Among the fruits found in the London Clay of Sheppey are conifers which have affinities to those now living in Africa and Australia.

The second main division of gymnosperms, the Cycadeæ, is represented in the Trias, Lias, and Oolite by some forms closely allied to those now living, and by others of very distinct groups which are no longer represented. In the ancient soil that forms the so-called "Dirt-bed" of the Purbeck series, associated with coniferous remains, are the "birds' nests," as they are called. These, although eggs are alleged to have been found in them, are, in fact, the stems of cycads; but unfortunately, in most cases their foliage and fruit is unknown. The discovery in the British Museum collection of a specimen in which fleshy fruits on short axillary branches are buried in the bases of the leaves led to the foundation of the genus *Bennettites*, named in honour of his predecessor; and a most anomalous form from the Oolite of Yorkshire, which is also represented in rocks of the same age in the south of Sweden and in India, was the basis of the genus *Williamsonia*, a true cycad, though anomalous, which he had named after a somewhat anomalous man, his old friend Professor Williamson, whom they were all glad to see there on this occasion. The Gnetaceæ are only represented in a fossil state by some species of *Ephedra* in Tertiary rocks, though the remarkable living genus *Welwitschia* has a very fossil-like appearance.

At the present day the gymnosperms are much scattered in their distribution. The cycads are represented in every quarter of the globe except Europe. *Cycas* itself, in which genus the seeds are borne on the margins of altered leaves, which are in the same series with the foliage-leaves, occurs in the Lias and at the present day round the Indian Ocean, having its head-quarters in India and Malaysia, but occurring also in Australia, apparently in Madagascar and, though only in temple gardens, in Japan. *Encephalartos*, with its fertile leaves in cones, is South African: *Bowenia*, with bi-pinnate leaves is an aberrant Australian genus: *Zamia*, with cones of flat peltate scales, like those of an Equisetum, is a native of the Southern United States and of the North of South America: *Dion*, another aberrant type, is North American; and the equally aberrant fern-like *Stangeria* is South African. Among the conifers *Pinus* is practically confined to the Northern Hemisphere, and, though abundant in the localities where they occur, many of its species are very limited in their area of distribution. So also are the species of *Araucaria*, which is now restricted to the Southern Hemisphere; whilst *Sequoia* is only represented by two species, both natives of California, though several cones referred to this genus have been found in the later Secondary and in Tertiary strata.

At the conclusion of Mr. Carruthers' remarks, the President proposed a vote of thanks to him and suggested that Professor Williamson should second his proposal. Professor Williamson, whilst heartily joining in thanking Mr. Carruthers for his remarkably comprehensive and lucid address, said that they had been fighting for years, but that there was only one subject on which he would fight on that occasion, and that was as to the Taxineæ, which Mr. Carruthers put at the top of the gymnosperms whilst he (Professor Williamson) would place them nearer the bottom. As a Darwinian, he preferred such a systematic position for *Sternbergia*, which after thirty years of controversy was now recognised as the pith of a tree (*Dadoxylon*) with wood resembling that of *Ginkgo*, and which was represented by several species as low down as the Devonian.

Mr. Carruthers in reply said that he regarded Professor Williamson as a "frightful example," since he first says that he is a Darwinian and then looks at facts from that point of view. As to the question at issue, in placing *Taxus* at the top of the series he was at least in agreement with the high authority of Messrs. Bentham and Hooker.

The party then adjourned to the outer galleries where the director pointed out *Cycas* with alternating large and small scars on the stem, those of the foliage- and seed-bearing leaves respectively, the allied *Yatesia* from the Potton beds, and *Palæoxylon*, which is probably the wood of the tree which bore the fruits known as *Trigonocarpus*.

EXCURSION TO ILFORD.

SATURDAY, 25TH MARCH 1893.

Director: F. C. J. SPURRELL, ESQ., F.G.S.

(*Report by the Director.*)

THE party assembled at Ilford station shortly before three o'clock, and leaving the station crossed the railway at the iron foot-bridge, where on either side of the path were seen old pits and those still in work. Those to the east showed the trail, the brick-earth (in which were numerous sun-cracks filled with sand and gravel), and below, the sandy portion of the mammalian beds, which are not now excavated for brick-making. In the upper brick-earth bones were found, as well as the following shells—*Limnæa peregra* Müll. *Planorbis marginatus* Drap., *Valvata piscinalis* Müll. ,and *Pisidium fontinale* Drap. The occurrence of all these shells is recorded in Mr. B. B. Woodward's list. No part of this pit showed the bottom.

The railway having been re-crossed east of St. Mary's Church, some smaller excavations were examined to the south east of that church. The party followed the high road into Ilford and turning aside had a glimpse of the great pits at Uphall, whence the greater part of the Brady collection (now in the British Museum) was obtained. These pits are not used at present except for building and market-garden ground. The party then divided, some going to Barking and some to London.

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EXCURSION TO NORWICH, THE BURE VALLEY, CROMER, AND LOWESTOFT.

Directors: THE PRESIDENT (H. B. WOODWARD, F.G.S.), CLEMENT REID, F.L.S., F.G.S., and J. H. BLAKE, Assoc.M. Inst.C.E., F.G.S.

I. NORWICH.

(*Report by* THE PRESIDENT.)

FIFTEEN years ago the Geologists' Association made an excursion to Norwich and Cromer, under the directorship of Mr. F. W. Harmer, Mr. H. B. Woodward, and Mr. Clement Reid, and then visited Norwich, Whitlingham, and Thorpe, and the coast-section from Sherringham to Cromer.

On the present occasion, the party left London on Thursday evening, March 30th, and arrived at the Maid's Head Hotel, Norwich, a little before 9 p.m., numbering altogether 47 members and friends.

Through the kindness of Mr. James Reeve, the Norwich Museum was open to the members until 10 p.m. on Thursday evening, and both he and Mr. J. T. Hotblack gave some account of the Gunn collection of Fossil Mammalia, and of other Norfolk fossils, to those who were able to pay a visit to this interesting museum.

On the morning of Good Friday Mr. T. Southwell and Mr. James Mottram kindly guided a number of the members through he new Museum buildings and the old Castle, and it was interesting to see the Fitch Room that is intended to hold the historic collection of fossils and antiquities presented by Mr. Robert Fitch.

Taking the steamer at Foundry Bridge at 10 a.m., a large party proceeded down the river to Bramerton. On the way, Mr. Mottram and the President called attention to various objects of interest; and the latter alluded to the disturbed chalk at Trowse and Whitlingham. At Trowse the Glacial Drift had been found beneath a tilted mass of Chalk and Crag, and at Whitlingham the Chalk was bent into a sharp anticline by glacial action, the disturbances being produced by the ice-sheet which formed the chalky boulder-clay, and which impinged in places against old banks or cliffs of Chalk. The phenomena, like the disturbed Chalk at Trimingham, served to explain the formation of the huge Chalk-boulders found in the Contorted Drift.

Attention was also drawn to the fact that William Smith obtained from the Crag at Whitlingham the tooth of Mastodon, figured in the frontispiece of his "Strata Identified by Organized Fossils," and described as belonging to "some extinct monstrous unknown animal." Reference was made to the former manufacture of gun-flints near Norwich, and some examples (from Brandon) were exhibited.

After a pleasant journey the party reached the Wood's End, where they landed, and after a short walk reached the famous Crag-pit of Bramerton. Here the members were soon busily engaged in collecting from the rich shell-beds.

The section is as follows:—

			ft.	in.
NORWICH CRAG SERIES.		False-bedded sand and gravel, with pebbles of flint and quartz [Bure Valley Beds] . . . . about	4	0
		Blue and brown clay [Chillesford Clay]	1	0
		Clayey sand with *Astarte borealis*, etc. [Chillesford Shell-bed]	2	0
	[FLUVIO-MARINE CRAG.]	Sand, with gravelly seams, and thin bands of clay; occasional shells (the beds masked by talus) . . . . . about	15	0
		White sand, full of shells, and with occasional seams of clay	6	0
		Stone-bed: layer of partially worn flints .	0	6
Chalk with flints: the surface bored by Crag Mollusca, etc.				

The more abundant shells in the Crag are *Tellina obliqua*, *T. lata*, *T prætenuis*, *Cardium edule*, *Mactra ovalis*, *Astarte compressa*, .*Mya arenaria*, *Mytilus edulis*, *Lucina borealis*, *Nucula Cobboldiæ*, *Pecten opercularis*, *Cerithium tricinctum*, *Littorina littorea*, *Trophon antiquus*, *Purpura lapillus*, and *Turritella terebra*. Fish-remains were also to be found, and one example of *Platax Woodwardi* was obtained.

The lower bed of Crag, which was well exposed, had been termed the "Fluvio-marine Crag," because a certain number of freshwater Mollusca were found in it; these were no doubt brought down by rivers. The deposit was essentially that of a shallow sea, and many of the shells, as remarked by Mr. Leighton, were drifted. The upper bed of Crag was concealed by talus, but it was soon opened up at one part of the pit. In it, the shells, as pointed out by Dr. J. E. Taylor in 1865, indicated slightly deeper water, and the more abundant forms were of more arctic character than those commonly found in the lower bed. This upper bed had been correlated by Searles Wood, jun., with the Chillesford shell-bed, while the Fluvio-marine bed was correlated with the upper part of the Red Crag.

The Crag section at Bramerton was the most famous one in the Norwich district. Sowerby and Searles Wood, sen., had obtained most of their Norwich Crag fossils from it; while in later years Mr. J. Reeve had added many species to the lists.

The following Mollusca were found by Mr. Leighton:—

	Norwich Crag, Thorpe.	Lower Crag, Bramerton.	Chillesford Crag, Bramerton.
Gasteropoda.			
Cerithium tricinctum, *Broc.*	...	×	...
Hydrobia subumbilicata, *Mont.* ...	...	×	...
Hydrobia sp.	...	×	...
Littorina litorea, *Linn.*...	×	×	...
Natica clausa, *Brod.* and *Sby.*	...	×	...
Purpura lapillus, *Linn.*	×	×	×
Scalaria clathratula, *Adams*	×	...	...
Trophon scalariforme, *Gould*	×	...	...
Pelecypoda.			
Astarte borealis, *Chemn.*...	...	×	×
Cardium edule, *Linn.*	×	×	...
Mactra ovalis, *J. Sby.*	×	...	...
,, subtruncata, *Da Costa*	...	×	...
Mya arenaria, *Linn.*	...	×	...
Pecten opercularis, *Linn.*	×	...	...
Tellina calcaria, *Chemn.* (lata, *Gmel.*) ...	...	...	×
,, crassa, *Gmel.*	...	×	...
,, obliqua, *J. Sby.*	×	×	×
,, prætenuis, *Leathes*	×	×	...
Venus fasciata, *Da Costa*	×	...	...

Scalaria clathratula, Adams, is recorded with a ? from the Norwich Crag in Searles Wood's monograph, and in Clement Reid's *Pliocene Deposits of Britain*. The specimen now collected is imperfect (apex and mouth wanting), but the fragment is in good condition. It agrees perfectly with the specimens in the Jermyn Street Museum from the Norwich Crag of Aldeby and Whitlingham, as also with the specimens from the Coralline Crag in the Searles Wood Collection.

Hydrobia sp. This is a remarkable shell, but too poorly preserved to name at present. It does not appear to belong to any species of *Hydrobia* or its allies recorded from the Norwich Crag Series.

Trophon scalariforme, Gould. This shell has been submitted to Mr. B. B. Woodward, who considers it a young specimen of the species. It is adorned with beautifully raised leafy costæ which presumably become absorbed (or worn away ?) with age. It is a remarkable shell, varying widely from the type, but it can only be referred to this species.—T. L.

A short visit was paid to an adjoining opening, known as Blake's Pit, where in the lower bed *Scrobicularia plana* occurs in some abundance. Here a portion of a deer's antler was found by Mr. R. W. Hinton. This was afterwards examined by Mr. E. T. Newton, who regards it as *Cervus Sedgwicki*? a species not hitherto recorded from any horizon below the Cromer Forest Bed. It was pointed out that the Chalk descends beneath the water-level a short distance east of Bramerton and Postwick; and that Eocene strata, which were proved in a deep well at Yarmouth, occur, beneath the superficial deposits, over portions of eastern Norfolk.

Returning to the Wood's End the members (after partaking of some refreshment) were ferried in detachments across the river. Along the way to Postwick Grove a good many recent freshwater shells were obtained from the mud that had been dredged from the river and placed on the bank. The Chalk and Crag at Postwick were too much obscured to justify any stay, but attention was drawn to the fact that here *Rhynchonella psittacea* had been found in the Norwich Crag, while the surface of the Chalk was bored by Annelides and Mollusca, a feature noticed also at Bramerton. A halt was made on the railway, and there Mr. Harmer mentioned the discovery, made many years ago by S. V. Wood, jun., and himself, of chalky Boulder Clay in the valley.[1] This glacial clay rested directly on the Chalk, and the ice by which it was brought had scooped through the Lower Glacial beds and Crag, and had thus helped to form that portion of the valley from Postwick to Trowse, where also this Upper Glacial clay had been found in the valley. The disturbed chalk at Trowse and Whitlingham, mentioned by the President, were connected with the same glacial action.

FIG. 1.—SECTION AT THORPE LIME-KILN, NEAR NORWICH.
H. B. Woodward.

			ft.	in.
NORWICH CRAG SERIES.	9. Pebbly gravel 8. Ironstone with casts of shells	[Bure Valley Beds.] .	12	0
	7. False-bedded sand, gravel, and clay-seams 6. Sand and clay	[Chillesford Clay.]	4	0
	5. Sand with shells 4. Pebbly sand (impersistent) 3. White sand with shells 2. Stone-bed, with shells and bones (1ft.)	[Chillesford shell-bed and Fluviomarine Crag.] . .	6	0
	1. Chalk with flints.			

1 *Quart. Journ. Geol. Soc.*, vol. xxiii. p. 89; vol. xxv. p. 448; vol. xxxiii. p. 84; and vol. xxxvi. p. 495.

Proceeding to the Thorpe lime-pit, the sections of Chalk and Norwich Crag were found to be splendidly exposed (Fig. 1). In the "stone-bed," or layer of partially-rolled flints that immediately overlies the Chalk, many mammalian remains had been found, among them the Mastodon, Elephant (*Elephas antiquus*), Antelope (*Gazella anglica*), etc. The identification of *Elephas meridionalis* is considered doubtful by Mr. E. T. Newton, although the species has been found in the Red Crag. Above this Stone-bed there were sands with shoals of shells, and the President pointed out that such shelly patches occurred only here and there in the Norwich Crag. At some places, even in the Thorpe pit, no shells might be found from top to bottom of the Crag; and elsewhere most of the sections would be found unfossiliferous, probably because in some cases the shells had been dissolved away by the action of carbonated water. In an ironstone band above the mass of Crag-shells, casts of shells were to be found. These included *Tellina obliqua*, *Nucula Cobboldiæ*, etc., and their occurrence was first noted by Professor Prestwich.

The members now proceeded along the lane towards the Plumstead Road, visiting pits in the brickearth (known as the "Norwich brickearth") that overlies the Norwich Crag series. This brickearth is of Lower Glacial age, and represents the Contorted Drift of the Cromer coast. Above it come the sands, grouped as Middle Glacial, beds which are often contorted with the brickearth. In the first pit, north of the Spinny, near Thorpe lime-kiln, the brickearth, a stony loam, was partially exposed; but the President remarked that in 1876 some remarkable contortions were shown on the western face of the pit, where streaks and nests of sand were incorporated with the brickearth. In the pit further north the beds were undisturbed, and there a marly earth (used for white bricks) was overlaid by brown sandy clay (used for red bricks), while sand and gravel rested on top. After a somewhat warm walk the members arrived at an oasis, the "Heartsease" on the Plumstead Road, where tea had been provided. Thus refreshed they proceeded to one of Mr. Moore's gravel-pits, where they saw the "cannon-shot" gravel, so extensively dug over the area of Mousehold. This gravel contains rolled and battered masses of flint, roughly resembling, as pointed out by S. V. Wood, jun., the "obsolete cannon-shot of from 12 to 32lb. calibre." Quartz and quartzite also occur. It is interesting to collectors, as the flints, derived from the Chalk, yield many fossils. In age this gravel is newer than the Chalky Boulder Clay, and is the latest deposit of glacial times in the area. It bears evidence of torrential accumulation, and may (as Mr. Wood thought) be due to the melting of the ice that brought the Chalky Boulder Clay.[1]

The last pit visited was that near the old Barracks, known as

1 See *Quart. Journ. Geol. Soc.*, vol. xxxvi., p. 500.

St. James's Pit, and there the Chalk was well exposed, with numerous nodules of flint and the larger forms known as potstones or Paramoudras. The President remarked that the Chalk belonged to the zone of *Belemnitella*, and that it yielded remains of the *Mosasaurus* (*Leiodon anceps*), *Belemnitella mucronata*, *B. lanceolata*, *Pecten concentricus*, *Rhynchonella plicatilis*, *Terebratula carnea*, and many Echinoderms, such as *Echinoconus abbreviatus*, *Cardiaster granulosus*, *Echinocorys vulgaris*, etc. Considerable discussion arose on the method of formation of the flints, but it was generally held that they must be due to processes of segregation, although in the first instance the silica was derived from sea-water by organic agency. This siliceous matter had aggregated around Sponges, Echini, and other organisms, and the nodules roughly coincided with the planes of stratification, like the septaria of the great clay-formations. Judging from the observations of Ehrenberg, Wallich, and others, it seemed likely that the nodules were formed during the gradual consolidation, stage by stage, of the Chalk ; even the paramoudras were but gigantic flints, and gradations might be found between them and the ordinary flint-nodules. Ehrenberg had thought that they were formed by the sinking of gelatinous silica into hollows of the soft Cretaceous mud.

From this pit the members returned to the Maid's Head by various routes, some across Pull's Ferry, and some by the Bishop's Palace. In the evening there was a large gathering at the Maid's Head, and the President gave a brief account of some of the geologists associated with Norwich, of Arderon, R. C. Taylor, Samuel Woodward, Joshua Trimmer, Lyell, John Gunn, Sedgwick, and lastly of the good work done by Mr. Harmer in his original geological survey of East Norfolk.

A boulder of fossiliferous Sandstone from Hartford Bridges, near Norwich, was exhibited by Mr. G. W. Page. It was uncertain if the specimen had been obtained from the Pebbly gravel (Norwich Crag Series) or from the Glaciated Chalk. The specimen was subsequently examined by Mr. E. T. Newton, who identified in it *Productus*, *Rhynchonella*, *Edmondia* and *Modiola lithodomoides*: the rock was no doubt of Lower Carboniferous age. A block of sandstone, of somewhat similar texture, was found by Mr. H. W. Monckton in the Bure Valley Beds at Great Hautbois.

II. Mundesley, Trimingham, and Cromer.

(*Report by* C. Reid.)

On Saturday, April 1, the members left Thorpe station at 9.8 for North Walsham, and drove thence to Mundesley, where they commenced the examination of the cliffs. The Mundesley river-bed, the first deposit examined, has yielded remains of *Elephas antiquus*, of the water-tortoise (*Emys lutaria*), and of the red-throated diver, besides fresh-water mollusca (*Hydrobia marginata*, etc.); the few plants yet found all belong to species still living in Norfolk. A mass of coarse river-gravel overlies the peaty loam which contains the fossils, and at the base of the loam is another gravel, in which have been found one or two somewhat doubtful flint-flakes. The whole mass, which was well-exposed, lies in a hollow eroded through the glacial deposits and cutting down to the Cromer Forest-bed. It is thus possible that the isolated tooth of *Elephas antiquus* may be derived from strata of much older date than the channel; but the other fossils are certainly contemporaneous with the formation of the loam.

Owing to the heavy rains of the latter part of the winter, and to the absence of the usual stormy weather of spring, the Mundesley cliffs were much obscured by rain-wash and mud; but the general succession of the Glacial deposits could be made out, and part of the underlying Forest-bed series was visible. The succession a few yards north-west of Mundesley is:—

GLACIAL	Gravel.	
	Stony Boulder Clay, streaky and full of small contortions (Contorted Drift).	
	Fine chalky falsebedded sand, unfossiliferous.	
	Chalky Boulder Clay, with fragments of marine shells (Second Till).	
	Arctic Freshwater Bed	Sections at present obscure near Mundesley.
PLIOCENE	Cromer Forest-bed	

Continuing towards Trimingham attention was drawn to the gradual increase of the Glacial disturbances, till the gentle undulations of the deposits have given place to sharp folds, and the Contorted Drift cuts through or has "eaten up" the older strata and plunges beneath the sea-level. The normal position of the Chalk is below low-water mark; but at Trimingham this disturbance has become so violent as to throw the solid rock into a series of undulations, which have the effect of raising it above the sea for about three-quarters of a mile (Fig. 3). The accumulation of sand and beach was too great to allow the alternation of Boulder Clay and Chalk on the foreshore to be examined; but two pinnacles or bluffs of Chalk were well seen in the cliffs, and photographs were taken by several of the members. One of these photographs, which Mr. A. Strahan has kindly lent, is here reproduced (fig. 2), for it shows better than any diagram the probable mode of origin of the large detached masses of Chalk included in the Contorted Drift near Cromer. The floor of Chalk at Trimingham has been bent up into a complete loop, the apex of which has been squeezed into the Glacial deposits, so that Boulder Clay actually passes under Chalk, as shown in the photograph to the left of the Chalk mass. This movement carried a little further would explain the origin of entirely detached masses, such as those illustrated in Fig. 4.

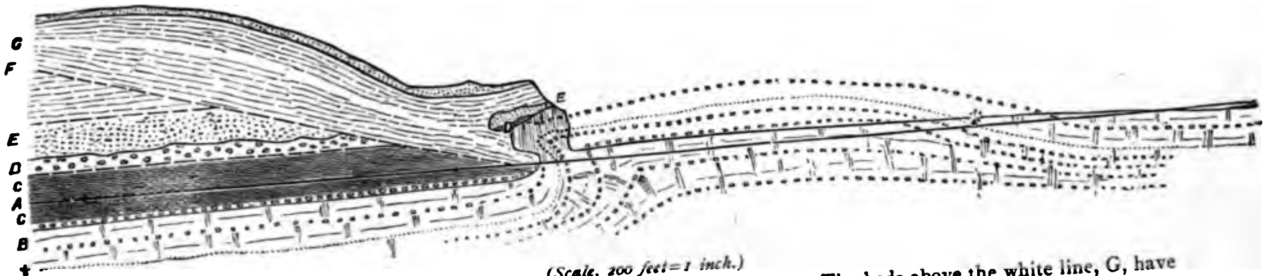
A few yards on each side of the projecting point undisturbed Forest-bed is exposed at the base of the cliff. Numerous small exposures of the Cromer Forest-bed were examined near Trimingham; but landslips and mud-streams prevented much being done in the way of collecting. One or two splinters of bone, some masses of driftwood, and a few fir cones (pine and spruce) were the only specimens obtained.

At Sidestrand the "Unio-bed" at the top of the Forest-bed

FIG. 2.—VIEW OF THE WESTERN CHALK BLUFF AT TRIMINGHAM SEEN FROM THE SOUTH-EAST.

was exceptionally well exposed, and some time was spent at this spot. Besides the abundant *Unio* (which appears to belong to *U. tumidus* and not to *U. pictorum* as given in the Pliocene Memoir) the deposit contains numerous *Pisidia* (*P. astartoides*, *P. amnicum*, &c.), *Bythinia tentaculata*, *Valvata piscinalis*, *Hydrobia marginata*, and other fresh-water shells; but has yielded few land-species. Some water-worn and broken cockles and tellens (*Tellina balthica*) were found mixed with the perfect though more delicate fresh-water species; but otherwise the whole of the fauna and flora belongs to a shallow lake, like the existing "broads" of Norfolk, or to the alluvial flats surrounding

FIG. 3.—SECTION AT RIGHT-ANGLES TO THE CLIFF THROUGH THE WESTERLY CHALK BLUFF AT TRIMINGHAM.—*C. Reid.*

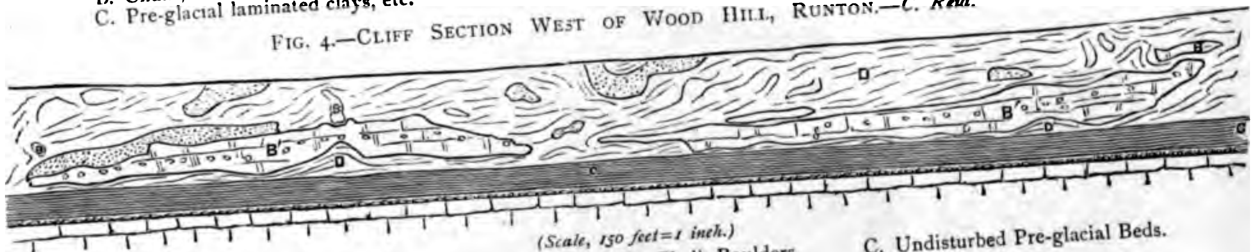


(*Scale, 200 feet = 1 inch.*)

A. Level of low-water spring tides.
B. Chalk, with sandy bed at +.
C. Pre-glacial laminated clays, etc.
D. Till.
E. Sands.
F. Contorted Drift.

The beds above the white line, G, have been seen and measured.

FIG. 4.—CLIFF SECTION WEST OF WOOD HILL, RUNTON.—*C. Reid.*



(*Scale, 150 feet = 1 inch.*)

A. Level of mean tides.
B. Chalk in place.
B'. Chalk Boulders.
C. Undisturbed Pre-glacial Beds.
D. Boulder Clay with masses of sand.

it. Seeds of the yellow water-lily, of pondweeds, and of the water-crowfoot are plentiful, and the water-chestnut has also been found. Remains of trees, except the alder, are particularly scarce in the Sidestrand Unio-bed.

At Overstrand an enormous mass of Chalk was pointed out in the Contorted Drift, and it was remarked that this erratic, which now occupies great part of the cliff, was first exposed about fifteen years ago. As the cliff is cut back the erratic appears larger and larger, but always lies above undisturbed Pre-glacial beds. It is undoubtedly entirely detached from the Chalk floor on the seaward side, but should be examined as the cliffs recede, to see whether it is perfectly isolated on every side, or whether it forms part of a loop, like that shown in Fig. 2.

The tide was rising fast, and the rest of the cliff-sections were much hidden by talus; so most of the members followed the path along the edge of the cliff from Overstrand to Cromer. After a cup of tea at Cromer they returned to Norwich by train.

III. The Bure Valley and Wroxham Broad.

(*Report by the President.*)

On April 2nd, about twenty-five members left by the 10.10 a.m. train for Wroxham, and embarking on board a small steam-launch, they journeyed down the river Bure to Wroxham and Salhouse Broads. These broads, as well as that of Hoveton, are separated from the main river-channel, being connected only by short dykes. It was pointed out by the President that the area was originally an estuary, but that eventually the sea was barred out by the accumulation of sand-banks. The broads occupy the deeper portions of the ancient estuarine area, some more or less isolated from the rivers, some in their direct course. All appear to be gradually decreasing in size, by the mud brought down by the rivers, and by peaty accumulations due to the growth of reeds and rushes which encroach along the banks.[1] Reference was made to the views of Mr. J. W. Gregory, who considered that at one time the broads of Wroxham, Salhouse, Woodbastwick, and Hoveton, formed one large broad, and that they were separated by the accumulations brought down by the river, and by the growth of reeds and rushes.[2]

Returning to Wroxham Bridge, the members landed and visited the brick-pit east of Wroxham station, where a fine "jamb" of laminated clay, regarded as on the horizon of the Chillesford Clay, was exposed. This clay was bent into a syncline, possibly by reason of an underground pipe in the Chalk, and it was overlaid by the pebbly gravels (Bure Valley Beds), and by traces of Lower

1 *Trans. Norfolk Nat. Soc.*, vol. iii., p. 439.
2 *Natural Science*, vol. i, p. 347. (July, 1892.)

Glacial brick-earth. After a substantial meal at the King's Head, the members again embarked on the vessel, and steamed up the river, past Wroxham Church and Belaugh to the old water-mill at Horstead. Here they landed and walked through Coltishall to a pit in the parish of Great Hautbois, where the Chalk and overlying Crag Series are worked. The Chalk was seen to contain bands of flint and one paramoudra. The Chillesford Beds here rest directly on the Chalk, and are very thin. In the stone-bed and basement-Crag remains of *Mastodon* have been found, especially in the old pits known as Little Switzerland, south of Horstead Mill. The Crag Series was not fossiliferous at this Hautbois pit, but the higher portion of pebbly gravel and sands that form the Bure Valley Beds was well exposed. This stage is characterised by *Tellina balthica*, which occurs at Belaugh, Aylsham, [1] and Weybourn. Small iron-stone nodules with ochreous kernels occur in these beds, and they have been attributed to the breaking up of clay-bands and the formation of clay-pebbles, around which the iron-oxide was subsequently deposited.[2]

Returning down the river to Wroxham Bridge the members took train to Norwich, and reached the Maid's Head about 6 p.m.

IV. WEYBOURN, SHERRINGHAM, AND CROMER.

(*Report by* C. REID.)

Monday, April 3rd, was devoted to the coast west of Cromer. Arriving at Cromer soon after ten o'clock the members were driven to Weybourn, where they were joined by Mr. Carruthers and Dr. Hicks. Under the guidance of Mr. Reid the cliff at Weybourn was first examined. There the Chalk was seen, overlaid by Weybourn Crag, above which were patches of gravel and loam belonging to the Cromer Forest-bed, the whole being covered by a streaky and marly boulder clay belonging to the Contorted Drift. Mr. Reid pointed out the abundance of the characteristic *Tellina balthica*, which in the Weybourn Crag appears for the first time; he remarked also on the importance of distinguishing clearly between the numerous minor zones in the Crag, which undoubtedly mark the passage of time and help us to understand how long a period we are dealing with. The arctic character of the Weybourn Crag marine fauna is very marked, but the associated land and freshwater species are all temperate or southern forms and closely connect the deposit with the overlying Forest-bed. A halt was made at Weybourn to allow of collections being made from the Crag, but as the sections farther east were much obscured by talus most of the members after-

1 Mr. R. J. W. Purdy has lately obtained *Tellina balthica* and other fossils from the Bure Valley Beds (equivalent of the Weybourn Crag) at Aylsham.

2 See *Proc. Geol. Assoc.*, vol. v., p. 514.

wards proceeded along the top of the cliffs to Sherringham, where lunch was taken at the Lobster Inn.

After lunch the members met again on the shore at Sherringham; the party now numbered about sixty, several others joining at this spot. The tide having fallen, attention was first drawn to the foreshore of Chalk, in which were seen abundance of paramoudras and large concentric rings of flint. A "stone-bed" like that found near Norwich rests on the Chalk and marks the base of the Weybourn Crag, over which lie the Cromer Forest-bed, the

FIG. 5.—CLIFF OF CONTORTED DRIFT WITH CHALK ERRATICS AT RUNTON.

(From a Photograph by Mr. Strahan.)

Arctic Freshwater Bed (no fossiliferous section of which was then visible) and the Contorted Drift. Near Beeston and Runton opportunity was taken to explain the origin of the peculiar schistose or fluxion structure so characteristic of the Contorted Drift This structure was formerly taken to represent bedding, but in 1878, during the last Excursion of the Geologists' Association to Norfolk, Mr. Reid pointed out that it was unconnected with stratification and was caused by the movement of the overlying mass. In fact it had nothing to do with sedimentation, but was more allied to the cleavage of slates or the fluxion-structure in igneous rocks. This view has only as yet gained partial acceptance, for at the time it was put forward schistose structure in the older rocks had scarcely been recognised as the result of movement, and the weight of all authority was against it.

The sections of the Contorted Drift between Beeston and Cromer were fairly clear, and Figs. 4 and 5 represent a portion of the cliff at Runton, where the erratic masses of Chalk are most abundant. At this point the cliff is 120 feet high and the

FIG. 6.—SCHISTOSE OR "AUGEN" STRUCTURE IN THE CONTORTED DRIFT AT BEESTON: HEIGHT OF SECTION ABOUT 10 FEET.

(From a Photograph by Mr. Strahan.)

largest mass of Chalk is apparently upwards of 500 feet long. These masses of Chalk tend to tail off at each end into white streaks in the Boulder Clay; they form in fact gigantic "eyes," such as are seen on a smaller scale in "augen-gneiss," where the movement has tended partially to crush large crystals of felspar and to cause the crushed particles to be drawn out into a streak in the gneiss.

Fig. 6 represents a section immediately above the beach at Beeston. It was conveniently placed for minute examination, and was closely examined by many of the members. Here the extreme effects of the movement were well illustrated, for the Boulder Clay and included masses of Chalk have been drawn out into alternating streaks, which, from a short distance, have all the appearance of irregular bedding, though in reality there is no trace of true bedding anywhere in this section.

At West Runton the black peaty deposit, which has yielded so large a number of plants and animals, especially of the smaller species, was partially exposed, but only a few seeds and fresh-water shells could be obtained. The complete section is as follows :—

Gravel with Palæolithic implements.
Contorted Drift.
Arctic Fresh-water Bed (sands), unfossiliferous and somewhat doubtful.
Sand and gravel with *Leda myalis* in the position of life.
Peaty loam full of seeds, shells, and small bones (the upper division of the Cromer Forest-bed.)
Estuarine gravel, sand, and clay, with bones of large mammals (Cromer Forest-bed).
Weybourn Crag.
Chalk.

The fossiliferous portion of the *Leda myalis* Bed has been entirely hidden under talus for several years, and it is still doubtful whether this deposit ought to be classed with the Crag or with the Glacial Deposits.

The members proceeded along the beach to Cromer, and, after tea, returned by train to Norwich.

V. Lowestoft and Kessingland.

(*Report by* J. H. Blake.)

On Tuesday, April 4th, the members left Norwich by train, at 9.15 a.m., for Lowestoft, which was reached at 10.26. They were then driven in a char-a-banc and waggonette to Kessingland, arriving about 11.30. After partaking of light refreshment at the "Sailors' Home," the members commenced their walk northwards along the sandy shore towards Pakefield and Lowestoft. Arriving opposite the flagstaff of the Coastguard Station, the director exhibited the Geological Survey Section of the cliff, drawn to a horizontal scale of 36 inches to a mile, and a vertical scale of 40 feet to an inch. He explained and showed by means of this section the position of the formations, which were much obscured in places in the cliff by blown-sand and talus. Chalky Boulder Clay (Upper Glacial), 20 to 30 feet thick in places, was shown to occur in the upper part of the cliff, underlain by well stratified and false-bedded buff sands (Middle Glacial) 30 feet thick; these rested on the Rootlet-bed (Forest-bed) 4 to 10 feet thick, which in turn was underlain by the Chillesford-beds, about 12 feet or more in thickness. Unfortunately these latter were obscured by blown-sand at the Kessingland end of the section; but the

Rootlet-bed, which extends continuously from Kessingland northwards to the *Unio*-bed, a distance of one and a-half miles, was very well exposed here and there at the base of the cliff. The small outlier of Chalky Boulder Clay, 4 to 5 feet in thickness at the Coastguard Station, was pointed out, and the party then proceeded onwards. The constituents of the Chalky Boulder Clay were carefully examined, and numerous striated boulders (some of which measure 3½ feet in diameter) of Chalk and Jurassic limestone were noticed and specimens obtained; also many derived fossils, among them being *Ammonites*, *Belemnites*, *Gryphœa arcuata* (*incurva*), *G. dilatata*, *Serpulæ*, etc. The very marked and even line which occurs at the junction of the Boulder Clay with the underlying sands was well shown in places. Fragments of marine shells were observed in the "Middle Glacial" sands; and many rootlets were seen in a vertical position as they grew in the Rootlet-bed, some measuring 4 feet in depth and 1½ inches in thickness. A portion of a leg-bone of a large Mammal was found in the Rootlet-bed about one mile from Kessingland, and dug out in the presence of several of the members. The carbonaceous clays and loams filling the shallow basin-shaped hollows cut out of the Chillesford-beds and Rootlet-bed, south of Pakefield Lighthouse Gap, were seen, but only one of the curved ends was exposed. The *Unio*-bed which occurs at the southern end of the second basin-shaped hollow from the Gap, was obscured by talus; and the ferruginous gravel containing Mammalian remains, situated beneath the Chillesford-beds and Rootlet-bed, was covered by beach-sand and shingle. A characteristic section of Chillesford-beds, consisting of alternations of very thin beds of laminated micaceous grey clay and brown sand was exposed at Pakefield Lighthouse Gap; after examining which the party continued along the shore, inspecting the cliff to the second Gap, where they ascended and walked into Lowestoft along the footpath on the top of the cliff.

Some of the members then accompanied the director to the end of the pier, where he pointed out the accumulation of blown-sand, beach-sand, and shingle to the north of the harbour, forming a strip of land about two and a-half miles in length, and nearly half-a-mile in width at its broadest part, in front of the old sea-cliff; this recent low-lying land forming the most eastern part of England.

After an excellent meat-tea, provided at the Royal Hotel, the members left Lowestoft by the 5.43 p.m. train, and arrived at London at 9.5. Thus ended a most enjoyable excursion, for the weather throughout was delightful.

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EXCURSION TO DARTFORD HEATH.

SATURDAY, 15TH APRIL, 1893.

Director: F. C. J. SPURRELL, F.G.S.

(*Report by the Director.*)

SHORTLY before reaching Dartford station, at the junction of the loop with the North Kent line, the attention of the party was directed to the *Cyrena* and Mammalian beds lying against a steep cliff of Chalk which could be seen at the time; and above them, higher up, the edge of the Dartford Heath gravel in festoons. On the hill east of the town more of the upper sheet was seen. Passing through the town the main sheet of Dartford gravel was entered on; and visiting Colonel Kidd's and other pits, interesting views of the varieties of gravel were seen. Some are dug for ornamental gravel, some for brick-earth, and some for ballast and building-sand. But the best view was obtained in the great pit at Wansum, forty feet deep. This showed below, large stone gravel unstratified; above this, about twenty feet of false-bedded sand and fine gravel; and higher still, the clayey layer constituting the gravel much valued for ornamental purposes. Implements have been found in the upper layer. A collection of pebbles with derived fossils was submitted by the director to the inspection of the party. Pebbles were easily procured which were foreign to the district and pointed to a connection with the Glacial gravels north of the Thames. The fossil finds of Mammoth and Rhinoceros, from more distant parts of the spread, were described.

The party, after crossing Cold Blow, the easternmost part of the great sheet of gravel, left for London *viâ* Bexley.

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EXCURSION TO BRILL.

SATURDAY, 22ND APRIL, 1893.

Director: PROF. J. F. BLAKE, M.A., F.G.S.

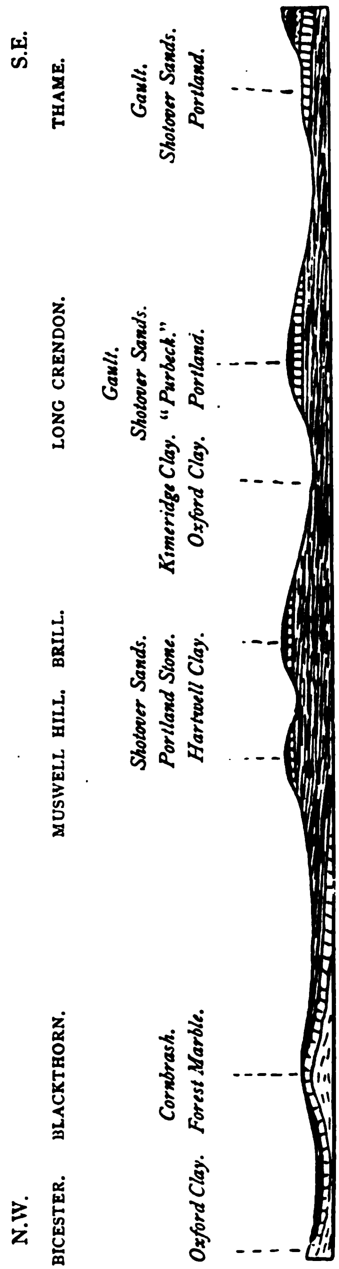
(*Report by* THE DIRECTOR.)

THE party from London reached Bicester Station at about 11 o'clock, and were at once conducted by the Director to the neighbouring brick-yard, in Oxford Clay, which here forms all the surface of the country. At this particular spot it lies in a shallow synclinal, the Cornbrash and Forest Marble coming up in the town to the west (whence several loads of the latter had been brought to the pit), and also, as was later seen, to the east. Hence the horizon here must be very near the base, and it thus happens that the highest ground seen from this spot—Graven Hill—is Oxford Clay to the top. The President (Mr. H. B. Woodward) stated that the clay here belongs to the Kellaways division. It was usual, he said, in Wiltshire and Oxfordshire to find immediately above the Cornbrash about 12 feet of clay, and this passes up into the sand, sometimes indurated into "doggers," which form the characteristic "Kellaways rock." At this brick-yard, sand overlying the clay has formerly been dug for making mortar.

Leaving this spot the party made their way over two miles of uninteresting country to Blackthorn Hill. Here there are old quarries which are worked through the whole thickness of the Cornbrash down to the Forest Marble below. Great masses of the latter lay on the quarry floor, and were searched for their characteristic fossils, *Acrosalenia*, etc. The side of the quarry next the northern road was then examined. Here the Cornbrash consists of rubbly limestone, separated from the Forest Marble by a band of white marl, the contrast between the two rocks being very marked. About 6 to 8 feet of Cornbrash are here seen, and the characteristic fossils, *Avicula echinata*, *Echinobrissus clunicularis*, *Terebratula obovata*, etc., are fairly abundant. Another opening at a lower level down the slope of the hill to the S.E. showed that this thin band covered a considerable area here, and in the stone-heaps other fossils, as *Homomya gibbosa*, *Pholadomya gyrota*, *Pecten vagans*, etc., were noted.

From this spot another three mile walk had to be taken, no exposures occurring till the summit of Muswell Hill was reached. It is supposed that the Lower Calcareous Grit, the Kimeridge Clay, and two members of the Portland series are here surmounted, but they make no show along this line of route. Numerous small openings, however, along the roadside showed

Section of Jurassic and Cretaceous Rocks between Bicester and Thame.—*J. F. Blake.*



Scale, 2 miles = 1 inch—heights exaggerated.

well the character of the overlying "Shotover Sands"—false-bedded, ferruginous, probably manganiferous in places, with occasional doggers and bands of white marl and sand. These are marked as "Lower Greensand" on the Survey Map, but it seems safer to give them a local name. There can be no question but that they form part of a deposit identical with, or corresponding to, that which is found on the summit of Shotover Hill and Cumnor Hurst, near Oxford. In all these places they are of freshwater origin, and it was interesting that on this occasion one of the party, Mr. A. G. Wildy, was fortunate enough to discover, in one of the nodules, a *Unio*, which has been identified by Mr. E. T. Newton, F.R.S., as *Unio porrectus*, a Wealden species. Later in the day the same kind of deposit was seen overlain by typical Gault and overlying "Purbeck"; so that we may see in it a lacustrine formation occupying any part or all of the period between these two. It is, however, extremely probable that part, at least, belongs to the later portion of this period, and is to be correlated in time, though not in circumstance, with the Faringdon Gravels.

On descending Muswell Hill, the clay-pits at the base of the next, or Brill Hill, were found to be in full operation, and, some fresh cover being removed, an admirable exposure of the Lower Portlandian was obtained. At the base of the section was some thickness of soft sandy clay, with *Perna*. This is doubtless to be correlated with the Hartwell rather than with the Kimeridge Clay. It corresponds, in fact, with the higher portion of the Clay series as seen at Swindon, where the true shaly Upper Kimeridge is seen below. Here, as there, this clay is followed by a remarkable rubbly glauconitic mass of shells, with a band of Lydian stones near the base. This Lydian stone band is not to be confounded with one which occurs at the base of the *Trigonia* beds, which are at a higher level.

If time could have been given, a very considerable collection of Lower Portlandian (Bolonian) fossils might have been collected, for the occasion was exceptionally favourable. The principal actually noted were:

Ammonites boloniensis	*Trigonia Pellati*
Am. biplex	*T. muricata*
Pleuromya tellina	*Perna Bouchardi*
Cardium Pellati	*Lima rustica*
Mytilus boloniensis	*Pecten lamellosus*

On the higher slopes of the hill the excavations in the Creamy Limestones were seen, but, as though by contrast to the lower beds, these upper ones were not well exposed, being largely covered by slips from the outlying Shotover Sands. Only the general nature of the series could be made out.

After some rest at Brill, the party trudged the tedious route to Long Crendon, where they were rewarded by a remarkable exposure, where four formations were displayed in about 12 feet of strata. In the quarry by the lower mill the top is seen to be Gault, though fossils are scarce. Then followed about 2 feet of the irregular ferruginous sandstone with which members had previously made acquaintance, representing all that is here left of the Shotover Sands. This lay on about 3 feet of well bedded limestones and marls of fine grain, in which it was easy to find a band full of *Cyprids* and scales and spines of fish, showing these to be the "Purbeck" beds of this district, while the base of the quarry was worked for the massive Portland limestone with *Trigonia gibbosa*.

On the descent of the hill towards Thame, some few of the party were able to notice the great changes which may occur locally in the base of the Portland; for here, instead of the fossiliferous beds seen on the west of Brill, about 20 feet of pure yellow sand are seen, while the Hartwell Clay is worked in the brick-yard at the base.

The party arrived at Thame in ample time for tea and the 7.5 p.m. train.

REFERENCES.

Geological Survey Map, Sheet 45 S.E.

1864. GREEN. A. H.—"Geology of the Country round Banbury, Woodstock, Bicester and Buckingham (Sheet 45)." *Mem. Geol. Survey.*

1880. BLAKE, J. F.—"On the Portland Rocks of England." *Quart. Journ. Geol. Soc.*, vol. xxxvi.

EXCURSION TO FARNHAM.

SATURDAY, 13TH MAY, 1893.

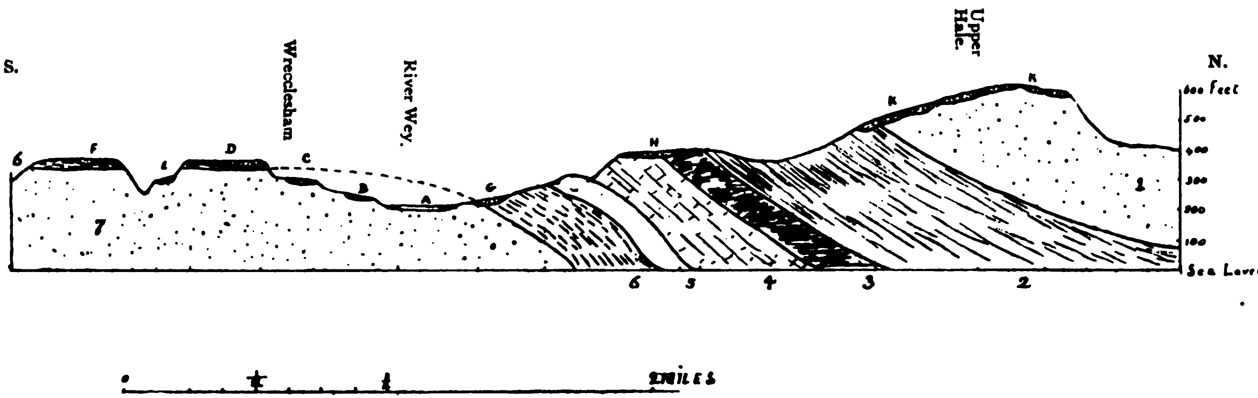
Directors: H. W. MONCKTON, F.L.S., F.G.S., and H. A. MANGLES, F.G.S.

(*Report by* THE DIRECTORS.)

THE party assembled at Farnham Station, and, by the kind permission of the railway authorities, and accompanied by the Stationmaster, Mr. Sumpster, they walked along the railway for about three-quarters of a mile to the west, and inspected a large sand and gravel pit worked by the railway company.

The gravel, some 10 feet thick, forms part of a somewhat irregular terrace about 250 feet above sea level. (B, fig. 1.)

FIG. 1.—SECTION THROUGH UPPER HALE AND WRECCLESHAM A LITTLE WEST OF FARNHAM.—*H. W. Monckton.*



A. Alluvium of the River Wey. B to H. Various patches of gravel. K. The high level gravel of Upper Hale and Cæsar's Camp, Aldershot.

1. Bagshot Beds. 2. London Clay. 3. Reading Beds. 4. Chalk. 5. Upper Greensand. 6. Gault. 7. Lower Greensand.

It rests upon the Folkestone Beds of the Lower Greensand, in which there is a very fine section, showing sand, beautifully false-bedded, with a little ironstone here and there. At one place near the top of the section the false-bedded sands are coloured green, but as a rule they are of various shades of buff, yellow, and orange. The sand is mostly coarse quartzose, and sometimes the grains are large enough to be called small pebbles. In this sand Mr. Leighton found a number of small fragments of shells, not, however, sufficiently well preserved for determination.*

There is not much ironstone in the sand here, and in this area it seems to be most abundant in the lower part of the Folkestone Beds.

Leaving this pit, the party walked to the village of Wrecclesham (or Wracklesham), and stopped for a few minutes at a small section a little north of the church, showing gravel resting on Folkestone Beds. The gravel is composed of flints, flint pebbles, chert, and small quartz, and is part of the terrace marked C in Fig. 1. Its level is about 300 feet above the sea, and 50 feet above the terrace B. At Wrecclesham it is thin, but it thickens to the north-east, and is over 12 feet thick at a gravel pit a little south of Farnham Station. The gravel of the two terraces B and C is mapped as one patch on the Geological Survey Map.

A section close to Wrecclesham Church was next visited, which gave rise to some discussion. It is described by Mr. Drew at p. 142 of Topley's "Weald," and the beds now shown are:—

7. Clay.	
6. Greenish sand and quartz grit with small quartz pebbles and scattered phosphatic nodules	1 ft. 2 in.
5. Clayey, gritty sands, few nodules	2 ft. 3 in.
4. An ironsand layer	0 ft. 1 in.
3. Yellow sand	1 foot.
2. Yellow sand with phosphatic nodules and fossils	1 foot.
1. Yellow sand.	

No. 7 is either Gault or reconstructed Gault. No. 1, according to Mr. Drew, is $4\frac{1}{2}$ feet thick, and is underlain by 4 inches of phosphatic nodules.

The following fossils were found in Bed 2:—

Nautilus (a fragment)	*Natica* sp.
Ammonites Beudantii, Brong.	*Pecten orbicularis*, Sow.
Ammonites interruptus, D'Orb.	*Pecten quinquecostatus*, Sow.

Now the question arises whether we should look upon the Beds 1 to 6 in the above section as the bottom bed of the Gault (zone of *A. interruptus*), or as the top bed of the Lower Greensand (zone of *A. mammillaris*). Mr. Drew observes: "In the

* Many of the fragments collected are only race, but undoubted shell fragments do occur, also some pieces of shell partly converted into race. An *Ostrea* can be recognised; there are also some tubular bodies which may be *Serpula*, but it is not quite certain whether they are organic at all.—T. LEIGHTON.

neighbourhood of Farnham the top bed of sand [of the Folkestone Beds] contains nodules of phosphate of lime, like nodules occur in the Gault just above; and, indeed, it is possible that both beds belong to the Gault, but the lowest is certainly in sand." (*Weald*, p. 141.)

The Gault clay was seen in a brickyard at the top of the hill above Wrecclesham, and a large fragment of shell was given to one of the party by a workman, and was said to have come from the bottom of the clay. Mr. Monckton thought that it probably came from a bed nearly answering to Bed 6 in the Wrecclesham Section, for the shell is filled with coarse sand similar to that of Bed 6. He thought it was almost certainly a fragment of *Exogyra sinuata*, Sow. and afforded evidence that the sand is really Lower Greensand, for that shell does not occur in the Gault, so far as he was aware. The other fossils occur both in the basement bed of the Gault and in the Lower Greensand.

In the section near Dorking, which the Association visited on July 9th, 1892 (see *ante*, p. 9), the bed with phosphatic nodules and *Ammonites interruptus* was seen resting on yellow and crimson sands, fairly evenly bedded; and in the brickfield on the east of the railway between Merstham and Red Hill, which was visited on May 21st, 1887,* the section was

Gault.—3. Very coarse quartz sand with much glauconite of a dark greenish grey colour.
2. Line of small phosphatic nodules.
Folkestone Beds.—1. Coarse yellow quartz sand.

Unfortunately none of these sections show the whole series from the Gault clay into the false-bedded sands of the Folkestone Beds; and perhaps at present it is safest to treat the sand with phosphatic nodules rather as the top of the Lower Greensand than as the base of the Gault.

Resting upon the Gault clay at the brickyard above Wrecclesham there was seen to be a gravel of irregular thickness. It forms a portion of the long sheet of gravel which caps a plateau running in a N.E. and S.W. direction parallel to the terraces B and C already described. It is marked D in fig. 1, and its level is from 360 to 380 feet above the sea. In places it is 25 feet thick, and it is nearly always well stratified near the bottom, and frequently quite unstratified near the top. The well-stratified part is nearly always seen to be more sandy than that which is unstratified. The gravel is mainly flint from the Chalk; but there are also flint pebbles from the Eocene pebble-beds, ironstone pebbles from the Folkestone Beds, some chert from the Hythe Beds, and some small quartz. The party walked along the top of this plateau, or ridge, and inspected a number of good sections.

Mr. Mangles informed the party that a considerable number

* *Proc. Geol. Assoc.*, vol. x, p. 156.

of flint implements have been obtained from this gravel. The majority are found near the bottom of the gravel, a foot or two above the Folkestone sand, but they range upwards to within three feet of the surface. Some have been actually picked up on the surface of the soil, but it is not improbable that they have been unearthed in opening the pits. Two of the largest pits have been worked out, and a move has now been made to a new pit on the east side of the Frensham road.

Before leaving the north face of the ridge, Mr. Monckton gave an address on the general geology of the district as seen northwards from that spot (see fig. 2). Mr. Mangles followed with a short account of Farnham Hundred, of the original fortress of Farnham Castle, of the visits of Queen Elizabeth to it, and of the part it played in the Civil Wars. Mr. Mangles also described the trade of the town since the beginning of the sixteenth century.

The party then walked to Waverley Abbey woods and halted under the trees for lunch.

After lunch the party, by the kind permission of Mrs. Anderson of Waverley Abbey, walked through the woods to the ruins, passing on the way a small gravel pit in a low-lying gravel, composed mainly of flints and of ironstone from the Folkestone Beds.

A short history of the Abbey (which dates from 1128 A.D.), was given by Mr. Mangles, and the details of the ruins were pointed out by the Rev. W. H. Edge, vicar of Tilford, after which the party crossed the river Wey and ascended Crooksbury Hill (534 feet). Mr. Mangles mentioned that a well at some cottages at the north foot of the hill had passed through 175 feet of the Folkestone Beds and entered a greenish calcareous stone of which some specimens were exhibited, all agreeing that they were Bargate Stone.

There is no section at the top of Crooksbury but several flints were seen on the surface and no doubt the hill which is formed of Folkestone Beds is capped by a small patch of gravel. Mr. Mangles remarked that this hill is called "Richard's Hulle," in Henry de Blois' grant of A.D. 1250.

The party then walked to Littleworth Cross, the residence of Mr. Mangles, and found an extremely interesting exhibition of flint implements set out on the terrace. The following are the details:

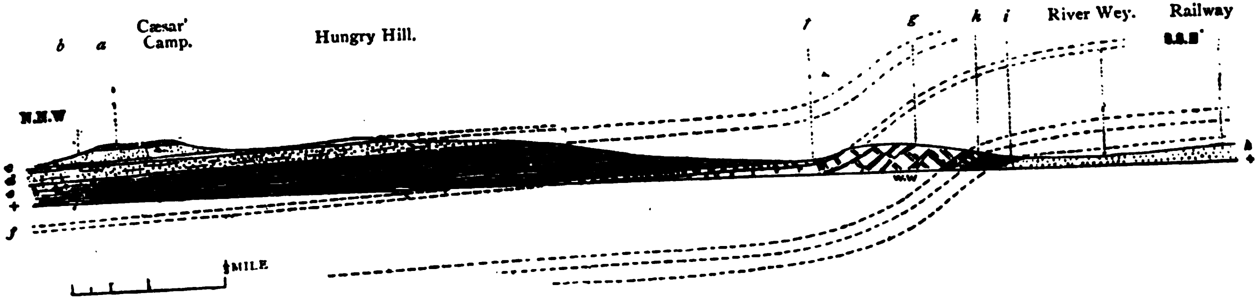
A series of flint implements from the Farnham gravels exhibited by Mr. Mangles.

(1) Implements from the gravel marked B in Fig. 1. These are without exception very much water-worn.

(2) Implements from gravel marked D in Fig. 1. These were arranged, as far as possible, according to the types as classified by Sir John Evans,* and included—

* "The Ancient Stone Implements . . . of Great Britain," London, 1872.

FIG. 2.—SECTION FROM CÆSAR'S CAMP, NEAR ALDERSHOT, BY FARNHAM PARK TO THE SOUTH-EASTERN RAILWAY NEAR FARNHAM STATION.—*W. Whitaker.*



Scale, horizontal and vertical : 2·4 in.=1 mile.

(*Reduced from the Geological Survey Memoir.*)

+ Sea-level (approximate.)

a. Gravel.
b. Upper Bagshot Beds (sand).
c. Bracklesham Beds (more clayey).
d. Lower Bagshot Beds (sand).
e. London Clay.
f. Reading Beds.
g. Chalk.
h. Upper Greensand. { Greensand. Malm Rock.
i. Gault.
k. Lower Greensand.

The broken lines above show the former continuation of the beds southward, and those below their present continuation underground northward.

(*a*) Pointed implements which may be described as acutely pointed, tongue-shaped, kite-like, ovate, ovate lanceolate, and sub-triangular; also a couple of thick-backed, single-edged implements, which appear to have served as knives or choppers of the roughest kind.

(*b*) Sharp rimmed implements. These may be described as ovate, oval, almond shaped, heart shaped, sub-triangular, and lunate or perch-backed.

(*c*) Borers.

(3) Neolithic implements (Celts and arrow-heads), from the neighbourhood of Farnham and the downs of East Hants.

(4) Two Palæolithic (?) implements from the drift in Griqualand, South Africa—almost identical in shape with the sharp rimmed implements of Farnham.

(5) A specimen block of breccia of sub-angular flint in a very hard siliceous sandy cement, some quantity of which has been dug up one or two feet below the surface in trenching land at the south-east foot of Crooksbury Hill.

(6) Corals from the Lower Greensand at the south foot of Crooksbury Hill. Mr. C. J. A. Meÿer observed that they resembled corals from the Bargate Stone horizon.

A series of flint implements from Farnham and one from Frimley, some of which are described and figured in the collections of the Surrey Archæological Society, exhibited by Mr. Frank Lasham.

A series of palæolithic implements from Farnham, exhibited by Mr. S. C. Hincks.

After the specimens had been examined the party adjourned to a tent where an excellent repast was provided by Mr. Mangles, to which full justice was done, and afterwards Mr. Mangles' beautiful garden was explored and a visit paid to the rhododendron house, where a collection of Himalayan and other rhododendrons was seen. Unfortunately it was too late in the season to see more than a very few of the species in blossom.

In the course of the day there was much discussion as to the age and origin of the various gravels. Mr. Monckton believed they were all river gravels, and stated that in the gravel F, which there was not time to visit, the proportion of chert from the Hythe beds is larger than in the gravels B C D, though the level was much the same as that of the implementiferous gravel D. The gravels B C D, he thought, were probably due to a river flowing from the south-west. The gravel E was a small terrace formed during the cutting out of the small brook which runs across Farnham Common, and the materials were probably derived mainly from gravels D and F.

Gravel G is an old river Wey gravel.

Gravel H is a patch not mapped, on the top of a hill half a mile west of Farnham Castle, and its composition seems to show derivation from gravel K.

K is the gravel of Upper Hale, Hungry Hill and Cæsar's Camp, Aldershot, which has been described.*

In many cases patches of these gravels seem to have slipped down hill or been lowered in level since their deposition, and this is probably largely due to underground waste, as recently described by our President.†

REFERENCES.

Geological Survey Map, Sheet 8 (Drift Edition).
New Ordnance Survey 1-inch Map, Sheet 285.

1875. TOPLEY, W.—"The Geology of the Weald," pp. 141-2, 149, 155, 199. *Mem. Geol. Survey.*

1892. LASHAM, F.—"Palæolithic Man in West Surrey." *Coll. Surrey Archæol Soc.*, vol. xi.

ORDINARY MEETING.

FRIDAY, 5TH MAY, 1893.

HORACE B. WOODWARD, F.G.S., President, in the Chair.

The donations to the Library, since the last meeting, were read, and thanks were accorded to the several donors.

The following were elected Members of the Association:—R. Marcus Gunn, M.A., F.R.C.S.; H. E. Armstrong, Ph.D., F.R.S.; W. P. D. Stebbing; A. E. Lardeur; R. Ll. Woollcombe, M.A., LL.D.; Uriah Dudley; Ed. Meeson; Fredk. Meeson; Wm. Saunders.

Mr. E. T. NEWTON, F.R.S., delivered a lecture on "The Reptiles of the Elgin Sandstones," which was illustrated by the oxy-hydrogen lantern.

Mr. DIBLEY exhibited Marcasite from Lyme Regis.

* *Quart. Journ. Geol. Soc.*, vol. xlviii. p. 30 (1892)
† *Natural Science*, vol. ii., no. 12 (Feb. 1893), p. 124.

ORDINARY MEETING.

FRIDAY, 2ND JUNE, 1893.

Rev. Prof. J. F. BLAKE, M.A., Vice-President, in the chair.

The donations to the Library, since the last meeting, were read, and thanks were accorded to the several donors.

The following were elected Members of the Association :—Miss Greville ; Miss J. Carpenter.

The PRESIDENT announced that a Special General Meeting would be held at 7.30 p.m., on Friday, 7th July, to consider some proposed alterations in the Rules.

A Paper was read by Dr. THUDICHUM, entitled "Some considerations of the Principal Phenomena connected with Volcanoes."

Dr. JOHNSTON-LAVIS exhibited a series of specimens from Vesuvius, illustrating the structure of Eozoon.

SPECIAL GENERAL MEETING.

FRIDAY, 7TH JULY, 1893.

In accordance with Bye-law XXI. a Special General Meeting was held, under the Vice-President, Mr. T. V. HOLMES, F.G.S, for the purpose of revising the Bye-laws.

After reading and discussion, the following were the alterations adopted in the Bye-laws of the Geologists' Association :—

The word Rules was substituted for Bye-laws.

Certain Rules were amalgamated, others transposed, and one new rule was added, necessitating various alterations in the numbering throughout.

In Bye-law IV. the privilege of introducing visitors at Meetings and Excursions was limited by the introduction of the words "except when otherwise ordered by the Council."

Bye-laws V. and VI. were amalgamated as Rule V.

Bye-laws VIII. and IX. were amalgamated as Rule VII. and it was provided that "the method of voting for the election of Ordinary Members shall be as follows : the name shall be read from the chair and the candidate shall be declared duly elected unless a ballot is demanded, in which case one black ball in six shall exclude, but no such ballot shall be valid unless twelve Members shall have voted."

Bye-laws X. and XII. were transposed and amalgamated as Rule VIII., and a proviso was introduced that Members "shall not be entitled to any of the rights or privileges of Membership until the Admission Fee and the first Annual Subscription shall have been paid."

In Bye-law XI. (Rule IX.) the Composition Fee was raised to £7 10s. for those Members elected in and after November, 1893.

The following new rule was added:—

> Rule XII.—"Any Member, whose conduct is, in the opinion of the Council, prejudicial to the interests of the Association, may be removed from the Association by the Council, by the vote of a majority of two-thirds present at a meeting of the Council, on the Agenda paper of which the words 'Removal of a Member' shall have appeared; provided that no Member may be so removed, unless due notice has been sent to him of the intention of the Council to proceed against him under this Rule, and of the nature of the charges made against him, and an opportunity has been afforded him of answering such charges, and of explaining his conduct to the satisfaction of the Council."

In Bye-law XV. (Rule XIII.), a proviso was introduced that each year "the new Council shall contain at least four Members who were not Members of the Council during the preceding year."

Bye-law XXIII. was transposed and became Rule XIV.

There were several other slight alterations, but these were merely verbal or grammatical.

ORDINARY MEETING.

FRIDAY, 7TH JULY, 1893.

T. V. HOLMES, F.G.S., Vice-President, in the chair.

The donations to the Library, since the last meeting, were read, and thanks were accorded to the several donors.

The following were elected Members of the Association:—Mrs. Florence Bond; Alex. Macdonald; John Kidd; Wm. Dixon Dent; Frederick James; Robert B. Webb; Prof. C. Lloyd Morgan; J. R. Tennear.

A paper was read by Mr. DAVIES, in the absence of Prof. W. JOHNSON SOLLAS, F.R.S., "On the Geology of Dublin and its neighbourhood."

Mr. GATES exhibited some Mammalian Remains found near Hendon.

A NEW READING OF THE HIGHGATE ARCHWAY SECTION.

BY W. J. LEWIS ABBOTT, F.G.S.

(Read 7th April, 1893.)*

THE succession and, indeed, the nature of the beds in the Highgate Archway Road has long formed the subject of a difference of opinion. Some observers, having seen the sands resting unconformably upon black London clay (as shown in the N. end of section II.), and noting various physiographical features of the surrounding country, have regarded them as Bagshots.† Others, having seen such sections as that exposed in the N.W. end of section I., where the fossiliferous clays pass insensibly into fossiliferous sands, gradually changing in colour from dark green to bright yellow, have disputed the claim of the sands to the term Bagshot, and have regarded them as "sands of the London Clay." Up till recently good sections were wanting, but in 1889 and 1890 the whole of the fields on the N. side were laid out for building purposes, and a large number of sections and cross-sections exposed. It will be unnecessary to describe all these, or to refer to them in the order in which they were made, or to detail the apparent anomalies they presented when viewed in the light of former opinions.

It will be remembered that the Archway Road runs N.W. and S.E., and that it is an artificial cutting through a hill. As the beds dip at a greater angle than the road, it is evident that the hill coincides with an upheaval, and is not entirely due to denudation. The various sections exposed showed the hill to be the end of a dome dipping in the direction of the road, and also almost at right angles to it, so that the succession and relation of the beds can be best shown by two sections taken in these directions. Section I. is compiled from various continuous exposures that were made parallel to the road for a quarter of a mile. In this distance there is a fall in the surface from 332 feet O.D. to 226 feet O.D. The foundations for the houses at the N.W. end of the section revealed the lowest bed exposed, No. 1. It is an unctuous clay, containing a band of *Rostellaria lucida* and three or four other species. This bed quickly passes into one which is a dark green highly fossiliferous glauconitic sand (No. 2), similar to a bed met with in Finchley Road sewer, where I obtained from it some fifty species, nearly all of which were also found at Highgate. I have further seen it in various sections round Hamp-

* [The title has since been modified.—ED.]
† "Geology of London," vol. i, p. 269.

stead, and Prof. Prestwich considers it to be the correlative of the bed at Brentwood, described by him in his Westleton paper.* It was this bed that yielded nearly all the fossils in the appended list. At this point it is about ten feet in thickness; it then becomes more clayey and of a light brown hue, thus passing into bed No. 3. This latter is never a decided clay, and at a distance of ten feet from No. 2 quite arenaceous conditions again obtain, the sand being of a light yellowish-brown hue, and the passage into No. 4 being gradual. Owing to previous excavations only about five feet of this sand could be examined at this identical spot, but in the bottom of it could be found casts of *Pectunculus decussatus* —a fossil which comes up from the glauconitic bed. Nor could the junction of beds Nos. 4 and 5 anywhere be seen, owing to the similarity of hue and composition, and the way the upper part of the former had been mixed with the lower part of the latter.

The continuation of the section to the N. and E. showed some 30 to 40 feet of sands (No. 5), in general appearance similar to No. 4, and for which they might easily be mistaken; but examination soon revealed a somewhat unexpected condition, showing them to be light micaceous bright yellow sands, with here and there thin seams of variously-coloured pipe-clay, and in some places intercalated seams of black London clay several yards in length and three or four inches thick, frequently dipping *against* the slope of the hill at an angle of 30 degrees. Sometimes they were very much iron-stained, and contained large quantities of angular chert (chiefly from the Lower Greensand), angular and worn ironstone and flints, white and variously coloured quartzites, sometimes in the form of pebbles, at others of angular and subangular boulders, boulders of sandstone and limestone, and here and there a pebble of chalk. This sand thinned out over the curved faces of beds Nos. 4, 3, and 2 on to No. 1, where it was followed by a most remarkable seam of pebbles from about two to four inches thick, which extended for 100 yards down the hill, till it was lost below the excavations. At some parts of this seam there were extremely large blocks of *Teredina*-bored wood, two or three feet in length and up to thirty inches in girth, together with large pyritised fossils such as *Nautili*. At G there was a remarkable gully, about fifteen feet wide, filled with pebbles and boulders, stuck at all angles, in a chalky clay. I also excavated from it a septarium nearly two feet long, of a bright yellow and red hue: this I have no doubt was from the Kimeridge Clay, as it was entirely unlike the accompanying septaria of the London Clay, which contained *Cardium*, *Modiola*, etc.

Flanking the hill was a bed of brown London Clay (No. 6), and although a re-deposit it extended the whole length of the exposed section, so that probably much of the clay towards Holloway is not *in situ* Sometimes as much as 15 feet of this material was

* *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 52 (1890)

shown, and it was this deposit that was worked for bricks. At S there was a large mass of black clay picked up, contorted, and spread out in the manner shown by the specimen exhibited.

By far the most extensive vertical cutting was that made in the formation of a crescent which backs towards Hornsey Lane, now laid out in unique terrace shrubberies and gardens. The crescent sweeping round into the heights on the N.E. revealed a continuous section, which may be regarded as being at right angles to section I, upon which its position is indicated by the dotted line. There were numerous supplementary sections exposed, but as they only repeat what is shown in these two, it is unnecessary to produce them. The excavations in section II. exposed some 30 or 40 feet of the upper sands (No. 5), which here follow the black London Clay, from which they are separated by a curious layer, several inches thick, of crushed black flints; the sands were sifted for mortar making, and the screened material employed for road and path metal. From the paths one could easily pick up at one stooping half-a-dozen angular pieces of chert and ironstone fragments, and half as many quartzites of various colours, together with the foreign materials previously described. This cross section also revealed bed No. 6 overlying No. 5 exactly as in section I., both being overlaid by made ground, 2 or 3 feet in thickness. About a hundred yards to the right, in Hornsey Lane, in several gardens into which I got access, the uppermost bed consists of a light brown sandy clay, similar to the lower part of bed 3. At no place beyond the limits of section II. did I see the sandy bed come to the surface, so that in all probability, in the part of the section shown, bed 2 is cut away, while further to the right bed 3 comes to the surface, as the ground again begins to fall.

During the excavations Mr. Starkie Gardner visited the sections, and he immediately pointed out the impossibility of bed No. 5 being of Eocene age, as he dislodged angular pebble after pebble from the walls, and observed that whatever overlaid it must necessarily be a re-deposit. I was further assured that in the construction of Highgate railway cutting a large gulley of sand cutting into the London Clay was encountered, which was connected with the underground drainage of the locality, and into which it was necessary to throw a very large quantity of bricks. This points to some far greater erosion in the locality than we, perhaps, have previously realised.

On the highest part of the Archway on the opposite side of the road to section I., the excavations for St. Aloysius' School were dug in a sandy gravel, consisting for the most part of well rounded flint pebbles of various sizes, from very small up to two or three inches long. If this gravel contained nothing but these its claim to Bagshot might be maintained, but unfortunately in addition to these well-worn rounded pebbles, we have numerous others quite small and absolutely angular, quite sufficient to invalidate its claim to Eocene age.

It is, of course, a little difficult to deal with a district like this, which has been cut into to such an extent in the formation of the Archway; and it is within the realm of possibility that much of the material in making the enormous excavation under that structure might have been shot over the face of the old hill and so have added to the complexity of the sections herein described. But the exposures extended over a distance of a quarter of a mile, and an aggregate thickness of nearly one hundred feet, which reduces the probability of man's intervention to practically an impossibility, while the presence and condition of the foreign materials appear to the author wholly inexplicable upon any other hypothesis than that herein advocated. I might add that upon examination of the materials Professor Prestwich has not only no doubt of their Southern Drift origin, but considers the discovery most interesting, although not altogether surprising, but on the other hand just what might be expected.

CONCLUSIONS.

1. That in the Highgate Section we have a gradual passage from dark unctuous clay, through glauconitiferous, to iron-oxide-stained sands, which in places are still *in situ*.

2. That these sands must be regarded as "Sands of the London Clay" and not Bagshot.

3. That the upper sands containing the constituent materials of the Southern Drift either belong to it or are a re-deposit of post-Eocene age, formed partly from the wreck of the Southern Drift.

4. That the way these sands invest the hill on the south, points either to their Northern origin or to their denudation at, or before, the deposition of the overlying clay.

5. That the "London Clay" of bed No. 6 although of considerable lateral extension, is a glacial re-deposit.

6. Granting the Southern Drift age of bed No. 5, the glacial deposits on the flanks of the hill bear the same relation to it that they bear to the Westleton Beds at Totteridge and other localities in the surrounding country. Further, a reference to Professor Prestwich's paper before quoted shows that he suspected at Highgate the existence of the Southern Drift.

List of Fossils from the London Clay.

Membranipora eocena.

Cœlopleurus Wetherellii.
Spines of Echinoderms.

Ditrupa plana, *Sby.*

Large crab, sp. nov. (?)

Pecten corneus.
Avicula media.
" papyracea, *Sby.*
Modiola simplex, *Sby.*
" constricta.
" elegans, *Sby.*
Arca impolita.
Pectunculus decussatus.
Nucula sericea, *Wood.*
Cardium niteus, *Sby.*
Lucina Goodhallii, *Sby.*
Astarte rugosa.
Cytherea tenuistriata, *Sby.*
" sp.
Tellina, 2 sps.
Syndosmya.
Solen affinis, *Sby.*
Corbula globosa.
" sp.
Teredina personata.
Rostellaria lucida.
" sp.
Murex coronatus, *Sby.*
Cancellaria læviuscula, *Sby.*
Pyrula nixilis.
Fusus trilineatus, *Sby.*
" regularis, *Sby.*
" complanatus, *Sby.*
" 3 or 4 sps.
Cassidaria nodosa, *Brand.*
" striata, *Sby.*
Pleurotoma teretrium, *Ed.* & 2 Vars.
" Wetherellii, *Ed.*
" terebralis and Vars.
" fasciolata, *Ed.*
" 4 or 6 sps. (?)
Metula juncea.
Voluta nodosa.
Natica labellata, *Lam.*
Sigareta, sp.
Diastoma, sp. (?)
Melania, sp. (?)
Phorus agglutinans.
Ringicula turgida.
Bulla, sp.

Otodus.
Lamna.
Various otoliths.

Highgate resin.
Websterite.

Explanation of the Figure.

Section I. is parallel to the Highgate Archway Road: length of section about ¼ mile.

Section II. is at right angles to Section I. (starting from it at the point indicated by the dotted line), and backing against Hornsey Lane.

6. Re-deposited London Clay.
5. Bright brownish-yellow sand with erratics.
4. " " " sand.
3. " " " sandy clay.
2. Highly fossiliferous glauconitic sand.
1. Unctuous chocolate-brown London Clay.

G. Gully with boulders in chalky clay.
S. Large mass of picked-up London Clay.

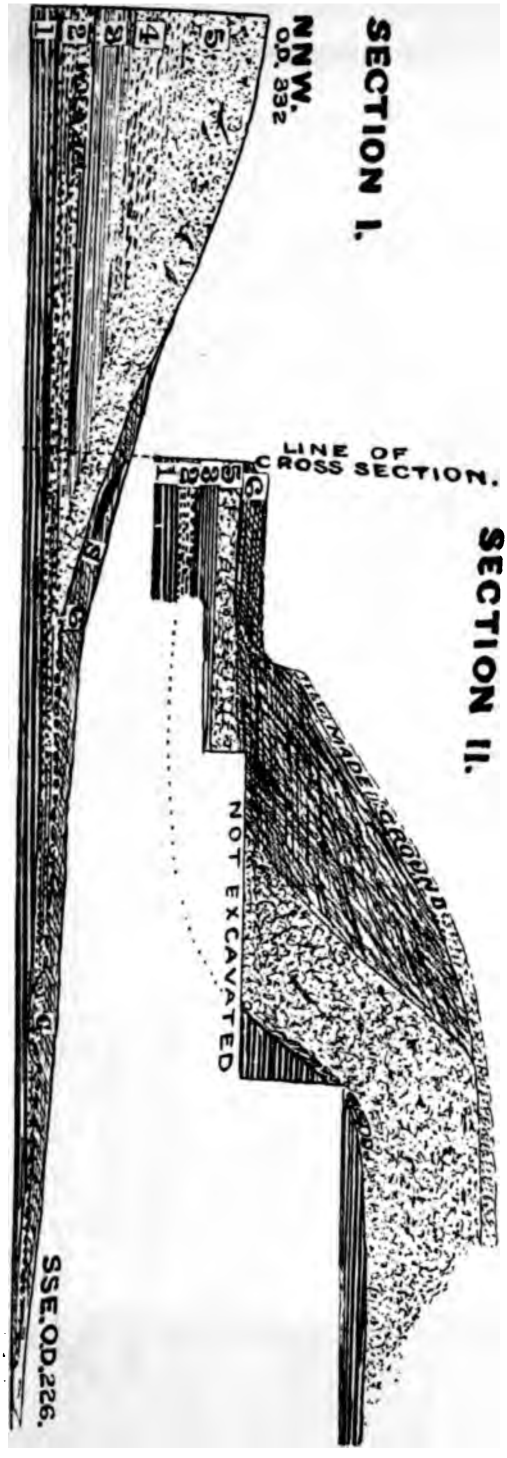

SECTION I.
NNW.
O.D. 332
LINE OF CROSS SECTION.
SECTION II.
MADE GROUND
NOT EXCAVATED
SSE. O.D. 226.

Fig. 1a.—Profile of the Country South of Dublin, from Bray Head to the Great Sugar Loaf, looking southwards.—(*After Weaver.*)

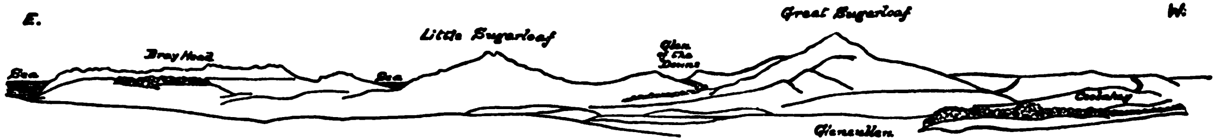
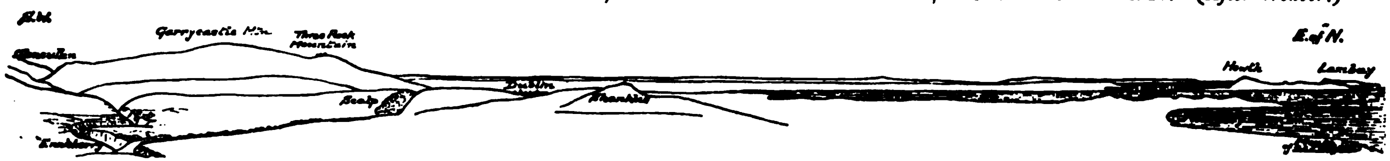


Fig. 1b.—Profile of the Country around Dublin, from Glencullen to Lambay, looking northwards.—(*After Weaver.*)



THE GEOLOGY OF DUBLIN AND ITS NEIGHBOURHOOD.

By PROF. W. J. SOLLAS, D.Sc., F.R.S, F.G.S.

[*Read 7th July, 1893.*]

THE pleasant hills of Wicklow, rising westwards from Bray Head in graceful curves, first into the Little Sugar Loaf and then into the Great Sugar Loaf, are the first land to come into view as the Holyhead steamer approaches Dublin Bay (Fig. 1A); as these are passed on the left there are soon seen looming on the right the steep cliffs of the rocky peninsula of Howth (Fig. 1B). The land to which the visitor is thus first introduced is the oldest in our district, antedating the Ordovician by a long but unknown interval. It consists for the most part of slates, grey, green, and red in colour, with occasional bands of grit, and numerous beds of massive quartzite, often of great thickness. It is one of these thick beds of quartzite which by its uniform texture and regular jointing confers upon the Sugar Loafs their symmetrical outline.

Origin of the Quartzite.—Uniform in texture to a remarkable degree, breaking with a fracture which while finely granular rarely reveals the presence of distinct grains, usually regularly interbedded with the associated slates and yet sometimes discordantly breaking across their edges, this rock has proved a source of great perplexity to the observer. Sometimes it has been classed, rightly as I think, with the common herd of altered sedimentary sandstones, sometimes it has been ranked as an igneous rock, and sometimes finally it has been regarded as the product of hot springs, the last offspring of expiring volcanic activity. The question is worth a little investigation, and first it may be remarked that though some portions of the rock may appear singularly devoid of rounded grains of sand, yet such grains are seldom entirely absent even to the unaided eye, and if rare in any one place they are abundant enough in others. It is true they are usually very small, under a millimetre in diameter, but occasionally they are larger and may attain a diameter of five or six millimetres, when they resemble little pebbles; they are then frequently of a different colour to the rest of the rock, and consequently very conspicuous.

The presence of these rounded sand-grains though highly suggestive of a sedimentary origin is not absolutely conclusive, and some observers as the result of microscopical examination have declared that the mass of the rock possesses the mosaic-like structure so characteristic of the quartz of some igneous rocks, such as granite, and such as conceivably might be produced in the silica deposited from hot springs. A searching investigation, however, fails to reveal the presence of this mosaic, and the structure which the microscopic examination of thin slices does really bring to light is that of rounded grains, the margins of which are usually clearly defined by various impurities, the commonest of these being sericite: the microscope proves indeed not merely that rounded grains are present, but that they practically compose the rock (Pl. iii, fig. 1). From this fundamental fact there is no escape, and we are consequently led to conclude that the quartzite rocks originally existed as loose grains of water-worn sand, which accumulated in shifting banks or wide stretching beaches off the shores of some ancient and vanished land.

If now we return to the examination of the rock in the field we shall find not only that it is distinctly interbedded with the surrounding slates but that in many cases it is finely banded by thin seams of darker coloured, more argillaceous material, which gives to it the appearance of having been at one time finely laminated.

The question will naturally arise as to how the originally loose sands became converted into compact quartzite, and this is readily answered by a microscopic examination of thin slices, from which we learn that in this as in so many other cases the grains of sand composing the rock underwent an increase of size subsequent to their deposition. The smallest fragment of any crystal placed in a solution saturated with material of its own composition will commence to grow in a definite fashion so as to restore to the fragment its characteristic geometrical outlines. The rounded grains of a sandstone are but worn fragments of crystals of quartz, and consequently when they find themselves immersed in a solution saturated with silica they commence to enlarge, and as they continue to grow would build up perfect little hexagonal prisms of quartz surmounted with the characteristic six-sided pyramid were it not that they find themselves closely surrounded by their neighbours who are also growing in the same way; there is no room to complete the crystalline form, and the extending outlines of the adjacent grains meeting one another interlock in a peg-like intergrowth, producing a union so close that without careful examination it might be mistaken for continuity. The subsequently added or secondary quartz is usually distinguished from that of the sand-grains by greater clearness and freedom from vapour cavities, so that even in the most compact quartzite the boundaries of the sand-grains can still be clearly distinguished. Frequently also minute flakes of sericite produced from impurities in the sandstone are formed between the sand grains, and the secondary silica inclosing these during its growth, leaves them as further evidence of the original clastic nature of the rock.

While silica deposited from solution has been the ultimate cause of the consolidation of the rock, earth pressures have played a powerful intermediary part. A slice of massive quartzite, which in ordinary light looks like a coarse conglomerate under the microscope, every grain being rounded like a pebble, undergoes a marvellous transformation when examined between crossed Nicols (Pl. iii, fig. 2): the sharp outlines of many of the pebbles disappear and a margin of granular quartz replaces them, showing that under excessive pressure the exterior of the grains was crushed to powder, to be subsequently re-cemented into a continuous mass by the deposition of silica from solution: under this pressure the grains have also been bent, moulded one to another, strained so as to give undulose extinction with polarised light, repeatedly cracked along planes lying in the direction of pressure, and partially converted into synthetic twins.

The cementing material was not in all cases silica: in rare instances the loose sand was permeated by ferruginous waters, and the grains are now cemented by ferrous carbonate; quartzites so produced might be distinguished as "siderose," a term more precise than ferruginous, as indicating that the iron is present in the state of carbonate.

The Grits and Grauwacke.—Great interest attaches to these rocks on account of the variety of their constituents, quartz grains like those of the quartzites are abundant; in addition there are others which are blue and opalescent like the blue quartz of the Sutherland gneiss; broken crystals of orthoclase felspar, and of synthetically twinned plagioclase which extinguishes at 12°, are also met with, as well as bleached biotite, together with excreted magnetite, chlorite, and an occasional crystal of zircon, apatite, and schorl.

The Slates.—While in the quartzite we recognise consolidated sands, in the slates we have evidently represented transformed muds and clays, some of which were originally almost pure kaolin, while others contained a large admixture of siliceous silt.

Transversal cleavage, though it does occur, is not common; over considerable areas the planes of easy splitting are directly descended from planes of lamination, so that one might on first thoughts be disposed to deny the applicability of the term slate and to suggest that of shales as being more appropriate; microscopic examination, however, while it fully supports the view that the rocks were originally shales reveals at the same time such an entire change in mineral composition, that the term shale ceases to be applicable: a felt of sericite now represents the clay, and sericite together with minute fragments of quartz, which are abundantly dispersed through it, the sandy mud; ferruginous impurities have collected with other constituents to form chlorite, which gives its characteristic green colour to the rock; an excess of iron beyond that required to form chlorite frequently remains over as ferric hydrate, and this masking the green colour renders the slate red. In some of the red slates, indeed, ferric hydrate is present to the total exclusion of chlorite.

It is a singular fact that though no signs of false bedding or current lamination have been observed in the thick beds of quartzite, yet in the slates, which are composed of much finer sedimentary material, this structure is frequently finely displayed. From the cliffs of Bray, hand specimens may be obtained showing repeated change in the direction of the current laminæ within a thickness of a few inches. Sometimes one is tempted to enquire whether this can be really current bedding, and to attempt to explain it by repeated folding and shearing consequent on crust movements.

Organic remains.—The quartzite of our district in its general appearance so forcibly recalls that of the Cambrian in Sutherland that one instinctively looks for the worm-tubes with which Messrs. Peach and Horne have made us so familiar, and though in the thick massive quartzite repeated search has failed to discover them, yet in certain of the thinner beds similar markings are far from rare; thus in a greenish quartzite near Periwinkle rocks, a little south of Bray, the late Dr. Kinahan discovered a number of large burrows with an expanded trumpet-like opening, three inches in diameter, and singularly resembling the "trumpet pipes" of Assynt, not only in form but in mode of occurrence; to these he gave the name of *Histioderma hibernicum* (Figs. 2 and 3). Again near "The Needles" of Howth, in pinkish coloured beds of sandstone, innumerable small worm-tubes about one-eighth of an inch in diameter occur running transversely to the planes of bedding, and these serve equally to recall the "small pipes" which occur on the lowest annelide horizon of Sutherland. So far then as both palæontological and lithological evidence are available they unite to suggest a Cambrian age for the oldest deposits of our district: if not Cambrian, they must be of still higher antiquity, as indeed is strongly suggested by the great unconformity which separates them from the succeeding Ordovician rocks.

Of the famous *Oldhamia* the systematic position is still doubtful, even its organic origin is not yet unanimously admitted: the excellent specimens of *Oldhamia radiata* preserved in the National Museum at Kildare Street are strikingly similar to the radiate branching markings which may sometimes be seen on muddy flats extending from the mouth of the tubes of burrowing worms, and since Dr. Joly has shown that the *O. radiata* markings (Fig 4) occur as grooves, depressed below the surface of the bedding planes on which they occur, it is very possible that this particular species may represent the trailing marks of the anterior end of a worm; but the same cannot be said of the second species

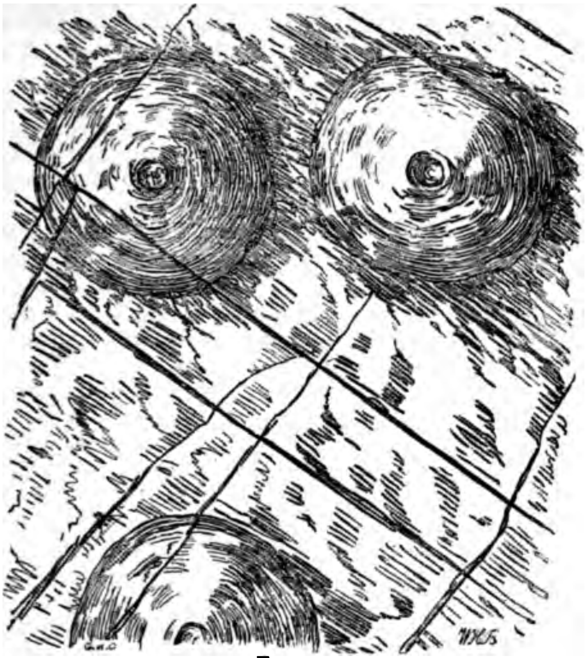


FIG. 2.

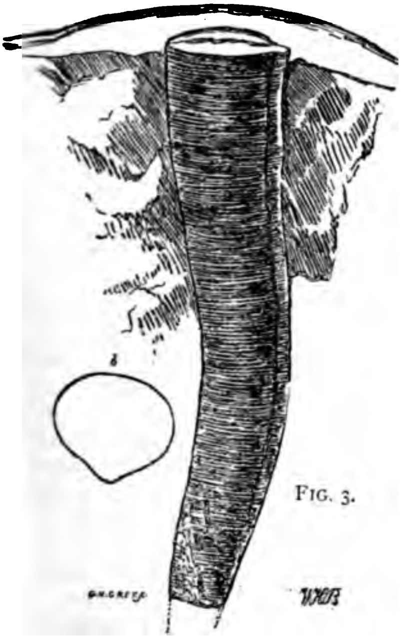


FIG. 3.

FIGS. 2 and 3.—*Histioderma hibernicum.*

FIG. 2.—THE UPPER ENDS OF THE BURROWS AS SEEN ON THE UPPER SURFACE OF THE "COMPACT GREENISH GRIT" IN WHICH THEY OCCUR.

FIG. 3.—LONGITUDINAL VIEW OF THE DOWNWARD EXTENSION OF THE BURROWS.

((× ½) From the *Memoir of the Geological Survey*, to accompany Sheets 121 and 130, p. 21.)

Oldhamia antiqua (Fig. 5), which occurs in relief as raised ridges on the upper surface of the bedding planes. For this peculiarity no explanation has yet been suggested.

To the list of problematical structures may be added certain spherical bodies with radiating spines which occur in the fine-grained greenish slate at Puck's Rocks, off Howth Head; if these are not merely mineral growths they are most probably Radiolaria.

Stratigraphical Succession.—Although highly disturbed faulted and overfolded, the rocks of Howth on the whole dip steadily to the South, so as to suggest that successively older rocks crop out northwards; and thus if we travel northwards over Howth we shall be approaching the base of the system. The actual base however is nowhere seen: a steep line of cliffs abruptly terminates the headland on the north, and at the western end of this line the Cambrian rocks disappear under the unconformably overlying Carboniferous Limestone. Possibly the base is not very far removed from this feature, the rocks here exposed consist to a great extent of sherd schist containing and indeed almost composed of fragments of slate and quartzite, so that one might fairly regard them as a conglomerate (rendered schistose by pressure) such as one would naturally expect to find near the base of a sedimentary system. Such a view cannot however be accepted in all its simplicity, since the included fragments of the sherd-schist are all of them similar in lithological character to the adjacent beds of quartzite, siderose sandstone, and slate, associated in the same series; many of the well rounded pebbles found in the sherd schist near the Nose of Howth may have been derived from the waste of an older land, but the majority have probably another origin as will be explained in speaking of the results of earth-pressure upon the rocks of the system.

We have now gathered the materials for the opening chapter in the history of our district, for the first scene in the long succession of its geographies. Our map is almost a blank, no land being visible, for of the rocks which now compose the province of Leinster, none had as yet been called into existence; all that we can at this early time discern is a shallow sea, lying over the site of the counties Dublin, Wicklow, and Wexford, and probably extending into Wales, but of the exact or even approximate position of its boundaries we know nothing: that, however, a great tract of land watered by rivers, and encircled by beaches and cliffs, existed not very far away, is rendered certain by the deposits which it furnished to the sea, and which formed the sands and muds of our Cambrian System: as these sediments were slowly piled in successive layers one upon another the sea floor as slowly sank, so that its depth remained fairly constant. In the stupendous mass of sediment thus tranquilly accumulated there exists in our district no trace of contemporary volcanic rocks; a long period of calm

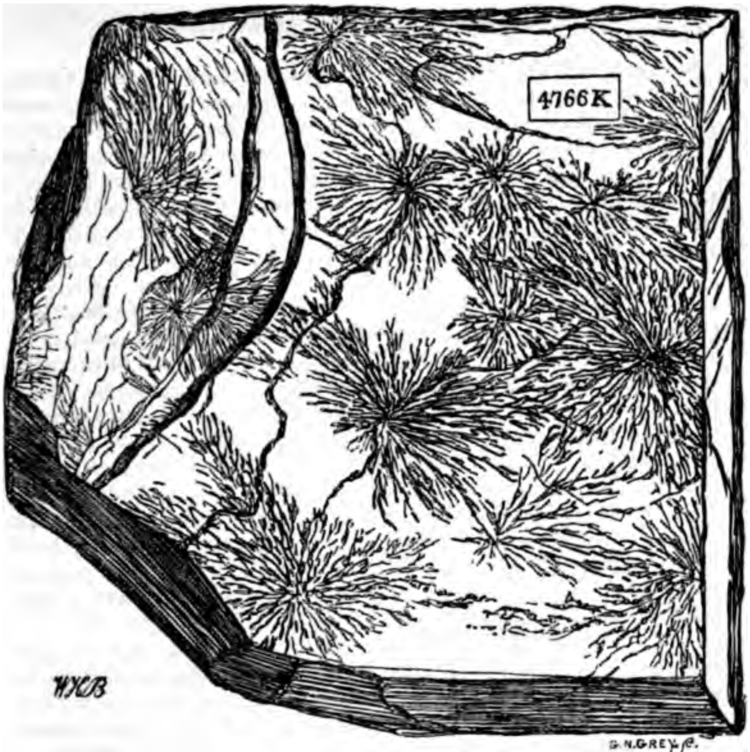


FIG. 4.—*Oldhamia radiata*, Forbes. (Nat. size.)

FIG. 5.—*Oldhamia antiqua*, Forbes. (Nat. size.)

thus preceded the igneous storm which burst out later on during Ordovician times. Signs of life were not absent, but they were neither numerous nor varied, as is shown both by the rarity of fossils and the entire absence of beds of limestone. In later times we learn to speak of "The Age of Reptiles," "The Age of Fishes": this was pre-eminently "The Age of Worms," a fact the full significance of which the Zoologist will appreciate, both as a sign of many Ages already passed away and as a promise and potency of Ages yet to come.

At length the long-continued subsidence of the sea floor and the deposition of sediment were brought to an end by great earth pressures and crust movements. Under the influence of these the soft muds were converted into slates and phyllites, and the sands into quartzite. With increasing pressure the whole series of beds was rolled up into anticlines and synclines, having a general strike from E.N.E. to W.S.W.: as the stress continued the quartzite of the anticlines gave way, the folds snapped and now occur with "broken backs," as may be seen near the bathing place on the north side of Howth, where a fault breccia, cemented into a hard rock by quartz, mends as it were the broken arch. Subsequent earth movements, the post-Ordovician and again the post-Carboniferous have affected these ancient Cambrian rocks, so that it is difficult to determine how much to attribute to each: in some cases the effects of subsequent pressures are evident enough as when well-cleaved Cambrian slate has been caught in a post-Ordovician squeeze and its cleavage planes sharply bent across into a series of parallel flexures. Such superimposed flexures are not uncommon in ancient rocks: a very good example is to be seen on the side of the road as one begins to ascend the Ober-Alp pass on leaving Andermatt. But as a rule we must for the present be content to observe the final result of the pressures without disentangling how much is due to each, and the study is an interesting one, thus in the cliffs of Howth vertical beds of quartzite and slate may frequently be seen traversed by horizontal faults, of no great throw it is true but fairly numerous: thus presenting on a very small scale a phenomenon which in Sutherland has carried slices of country in a horizontal glissade miles away from their original position. Or again as on the north side of Howth one may observe how great blocks of quartzite have been squeezed out from their bed during folding and carried into a stream of flowing slate to form veritable intratelluric erratics. Near the Nose of Howth whole trains of such erratics may be seen: these no doubt stand in connection with an important plane of shearing along the middle limb of an overfold. To such movements as these the greater part of the sherds in the sherd schist of the N. part of Howth is due. The whole terrane seems here to have been thrown into a state of intestine movement, flowing up, down and sideways, and even whirling round about. Abundant justification is thus afforded to those earlier clear-sighted observers who like Mr. John Kelly conceived that the quartzite beds "no longer retain the place which they originally occupied with regard to the surrounding slates."

The pressure which thus set in intestine movement the oldest rocks of Leinster at the same time elevated them above the sea, converting them into lofty land which persisted through the whole of the Upper Cambrian period. In our area there is consequently a marked absence of Lingula flags and Tremadoc slates.

At length "the revolutions of the times" brought round a movement of depression, and "the continent, weary of solid firmness," sank beneath the waters of the Ordovician sea. Over the upturned and denuded edges of the Cambrian strata dark-coloured muds and sands were strewn and continued to accumulate till a mass of sediment, probably some thousands of feet in thickness, was laid down. In the lowest beds of this deposit fragments of Cambrian slate are sometimes to be found. Over wide areas and through a great thickness the deposit is as barren of all signs of life as the rocks of the preceding system; but here and there in more favoured localities, as at Portraine and near Rathdrum, fossils occur in rich profusion. As is frequently, if not usually the case, in the Ordovician rocks of Leinster, these fossiliferous zones are associated with the products of volcanic activity; and those who think they recognise in the Ordovician slates the deposits of an abyssal sea will naturally find in this association a confirmation of their views, since in the neighbourhood of volcanos we should expect to find the shallower waters of the sea and the thickly-peopled zones which lie round a coast. To those on the contrary who find in the sandstones associated with the slates an indication that the latter were laid down not in abyssal depths but in comparatively shallow water, an equally natural explanation is forthcoming, afforded by the fact that both the fossils and volcanos associated with them are of Bala age, and thus mark the closing period of the Ordovician, when the depression of the sea floor had reached its maximum and the shores of the adjacent land had consequently retired farthest from our area. With the retreat of the source of sediment the sea would have naturally grown clearer and its waters more favourable to the existence of animal life.

The small area of Ordovician rocks exposed at Portraine is of surpassing interest, bringing as it does almost to our doors, an example in miniature, of that curious intermixture of organic and volcanic products which is so noteworthy a feature in the great ancient coral areas of the Tyrol, and which may be studied in actual process of formation in existing coral seas. Commencing at the north end of the section (Fig 9.) along the coast a complex of lava flows with intruded dykes is met with. The lavas are green and purplish diabases or porphyrites (Fig. 6), frequently porphyritic with large crystals of lime-soda felspar, and sometimes also of augite; they are frequently highly vesicular, the vesicles being now filled with calcite, chlorite, and sometimes quartz. Proceeding southwards

FIG. 6.

SECTION OF THE PORPHYRITIC LAVA OF PORTRAINE.

(× 17 dia.), *Cl*, Chlorite, in the upper right-hand corner replacing augite, in the lower right-hand corner filling a vapour cavity, which is lined with chalcedony, and surrounded by granules of magnetite. *C*, Calcite. (Original.)

FIG. 7.

SECTION OF VOLCANIC ASH FROM PORTRAINE.

(× 15 dia.) *Il*, Ilmenite; *Q*, Quartz; *P*, pumiceous glass with elongated vesicles. The other fragments are chiefly rolled pebblets of glassy lavas. (Original.)

there succeed beds of slate or shale, largely composed of volcanic ash and crowded with lapilli (Figs. 7 and 8), rolled fragments of lava-froth, as vesicular as pumice (though the vesicles are usually round, rarely elongated), pebbles of andesite and trachyte, together with fragments of organisms, including whole coralla of *Favosites* and *Halysites*; intercalated are beds of black slate (once marine mud) containing *Graptolites*, of which the commonest, as determined by Mr. Bailey, is *Diplograpsus pristis*; a little further along the coast beds of grey limestone, largely composed of corals and evidently representing an ancient coral bank, are reached; the limestone is very pure and highly crystalline, but in its purest and most massive parts occasional fragments

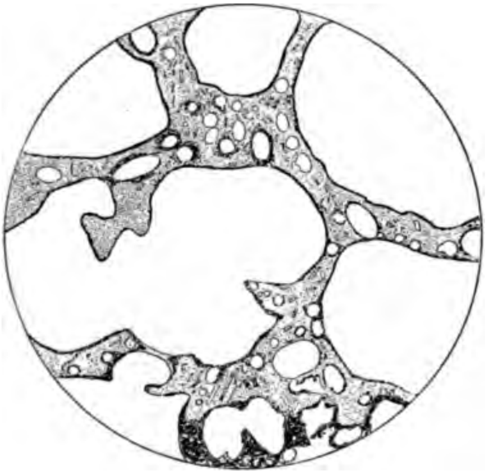


FIG. 8.

SECTION TAKEN FROM A ROLLED PEBBLE (2 INCHES IN DIAMETER) OF HIGHLY VESICULAR GLASS FROM PORTRAINE (× 17 DIA.). (Original.)

of felspar may be discerned under the microscope. Many of the included fossils are silicified and covered with "beekite," and traces of sponge spicules (originally siliceous, but now calcareous) are to be seen in thin slices of the rock.

The following list of fossils found in the limestone we owe to the late Mr. Bailey:—

Cyathophyllum, sp.	*Favosites cristatus*, Blum.
Favosites asper, Blum.	*F. fibrosus*, Goldf.
Halysites catenularis, Linn.	*Heliolites interstinctus*, Wahl.
Syringophyllum organum, Linn.	

Ptilodictya dichotoma, Portl. *P. acuta*, Hall.

Atrypa marginalis, Dalm.
Leptæna quinquecostata, M'Coy.
Leptæna tenuicincta, M'Coy.
Orthis biforata, Schlot.
Orthis elegantula, Dalm.
Orthis porcata, M'Coy.
Orthis vespertilio, Sow.
Strophomena rhomboidalis, Wilck.
Discina, sp.
Leptæna sericea, Sow.
Lingula sp.
O. calligramma, Dalm.
O. insularis, Eichw.
O. testudinaria, Dalm.
Strophomena alternata, Conr.
S. expansa ? Sow.

Ctenodonta sp.

Cyclonema Rupestris ? Eichw.
Euomphalus sp.
Murchisonia sp.
Bellerophon n.s. allied to *B. acutus*, Sow.
Holopæa concinna, M'Coy.
Raphistoma sp.

Orthoceras remotum, Salter MS.
O. tenuicinctum ? Portl.

Tentaculites anglicus, Salt.

Agnostus trinodus, Salt.
Calymene obtusus, M'Coy.
Cheirurus bimucronatus, Murch.
Illænus boumanni, Salt.
Lichas laxatus, M'Coy.
Sphærexochus mirus, Beyr.
Trinucleus seticornis, His.
Aeglina mirabilis, Forbes.
Cheirurus clavifrons, Dalm.
Cybele verrucosa, Dalm.
Lichas hibernicus, Portl.
Remopleurides longicostatus, Portl.
Stygina latifrons, Portl.

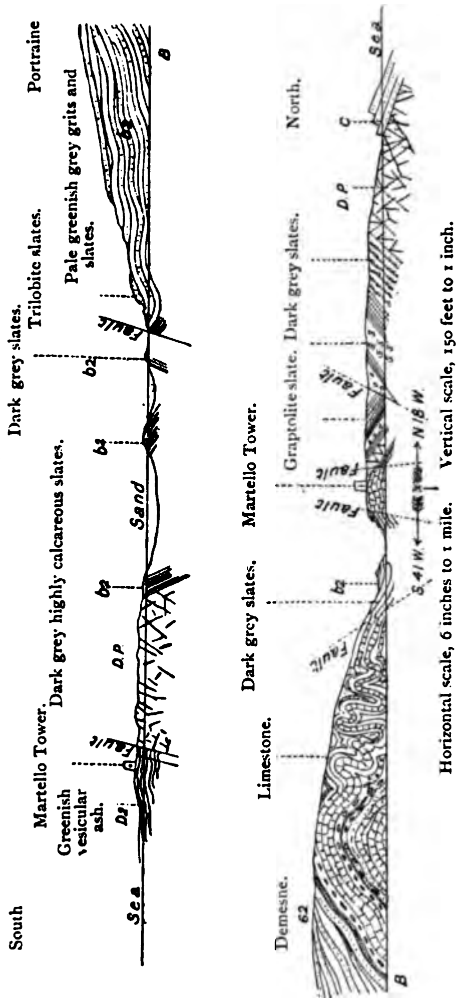
With the preceding facts before us, the interpretation is not difficult. Somewhere near Portraine * (Professor Cole suggests at Lambay) was situated an active volcanic cone, its shores washed by the waters of the Ordovician sea, beneath which its flanks extended as the sea-floor. A living plexus of organic forms mantled round, and fringed it with reefs of corals and shells. Ever and anon the thunders of its explosions heralded a rain of falling ashes and lapilli, and outbursts of molten lava streams. Incessantly the waves sounding on the beach and pounding upon the reefs were washing them away, breaking off fragments, rolling them into pebbles and commingling all, limestone from the reefs and lava and ash from the cone, to form the thick successions of deposits which now extend from Donabate to Portraine. Quiet intervals evidently there were when the sea-floor escaped the continual wash of the waves, and black mud brought from some unknown land was deposited to form the beds where we now find the remains of *Diplograpsus pristis*.

The volcano of Lambay is the most northerly outpost of a whole chain of volcanos which extended through the Ordovician

* The island of Lambay is one of the best preserved remains of an Ordovician volcano in the British Isles. During a recent visit I found that the greater part of the "green porphyry" is composed of beds of volcanic ash and agglomerate, which includes fragments of vesicular scoriæ, resembling bombs, sometimes more than a yard in diameter.

sea of Leinster, to culminate in County Waterford. One of these cones lay near Roundwood, where basic lavas were extruded, and where still may be traced ashes and agglomerates and variolitic

FIG. 9.—SECTION ACROSS THE ORDOVICIAN SERIES OF THE PROMONTORY OF PORTRAINE (*Geological Survey of Ireland*).



glass. Another was situated near Rathdrum, where vesicular andesite and silicified lava-flows are now to be found.

With the volcanic deposits of the Bala the Ordovician system terminated. A folding of the earth's crust which affected Ireland, Wales, Scotland, and Scandinavia succeeded, the Ordovician sediments were contorted, plicated, overthrust,* cleaved into slates, and elevated above the sea level, with a general strike running from N.E. to S.W., and this also was the primitive direction of a lofty mountain dome to which they gave rise, and which had its greatest elevation along a line running from Dublin to New Ross. The core of this dome was a mass of granite, which has since been revealed by denudation, and now forms the granitic mountainous range of Leinster, the largest exposed mass of granite in the British Isles.

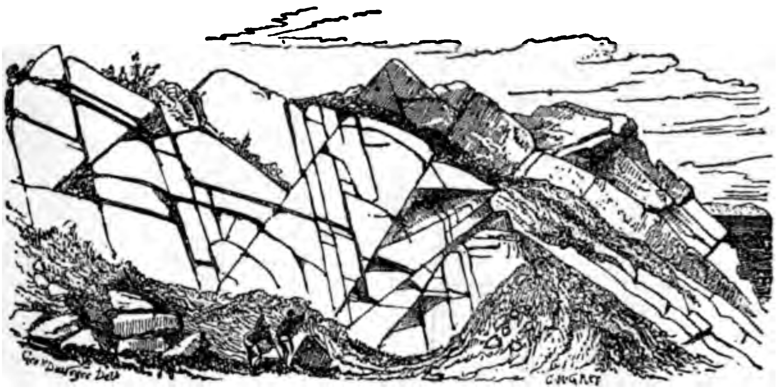


FIG. 10.

GRANITE ON THREE ROCK MOUNTAIN, SHOWING DIFFERENT MODES OF JOINTING, THE PLATY JOINTING ON THE RIGHT GIVING A DELUSIVE APPEARANCE OF BEDDING.

(From the *Memoir of the Geological Survey*, to accompany Sheets 102 and 112, p. 28.)

It is a singular fact, first insisted on by Jukes, that the sedimentary rocks directly in contact with the granite are invariably Ordovician, never Cambrian; sometimes, as at Shankill, the Cambrian come perilously near, but never touch it, the Ordovician, faithful to their rôle, still intervening in a narrow band. The Ordovician visibly adjoin because they overly the granite. Can it then be, one is inclined to enquire, that the Cambrian are not seen because they underly and are consequently concealed by it? If so, the granite core is of the nature of a laccolite, with the Ordovician for a cover and the Cambrian for a floor (Fig. 11).

The folding and elevation of the Ordovician sediments was a slow process; how slow we cannot even guess, since the earth has never presented to human observation a mountain-building phase. The invasion of the granite was equally slow, every upward yielding of the sediments under the great earth pressure being

* A striking example of an overthrust is to be seen at Portraine, where a part of the Bala limestone has been shoved for some hundreds of feet along an almost horizontal plane.

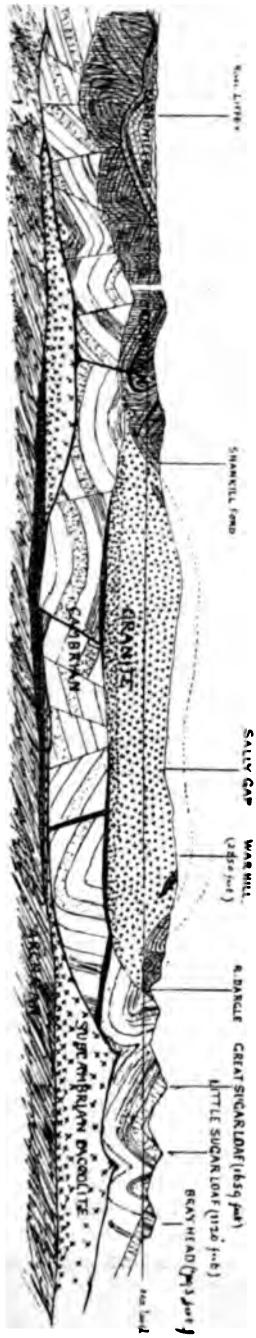


FIG. 11.—HYPOTHETICAL SECTION THROUGH THE NORTHERN END OF THE GRANITE RANGE OF LEINSTER, FROM BRAY HEAD TO SALLY GAP, AND THENCE TO RATHCOFFEY.

accompanied by an inrush of granite into the hollow of the rising arch: inch by inch, throb by throb, the mighty complex of igneous and sedimentary rock was uplifted into the air till it presently attained an altitude comparable to that of an Alpine chain, even still after all the vicissitudes to which it has been exposed attaining, as at Lugnaquillia, an altitude of over 3,000 feet.

The extreme slowness of the elevatory movement must constantly be kept in mind in studying the problems connected with it.

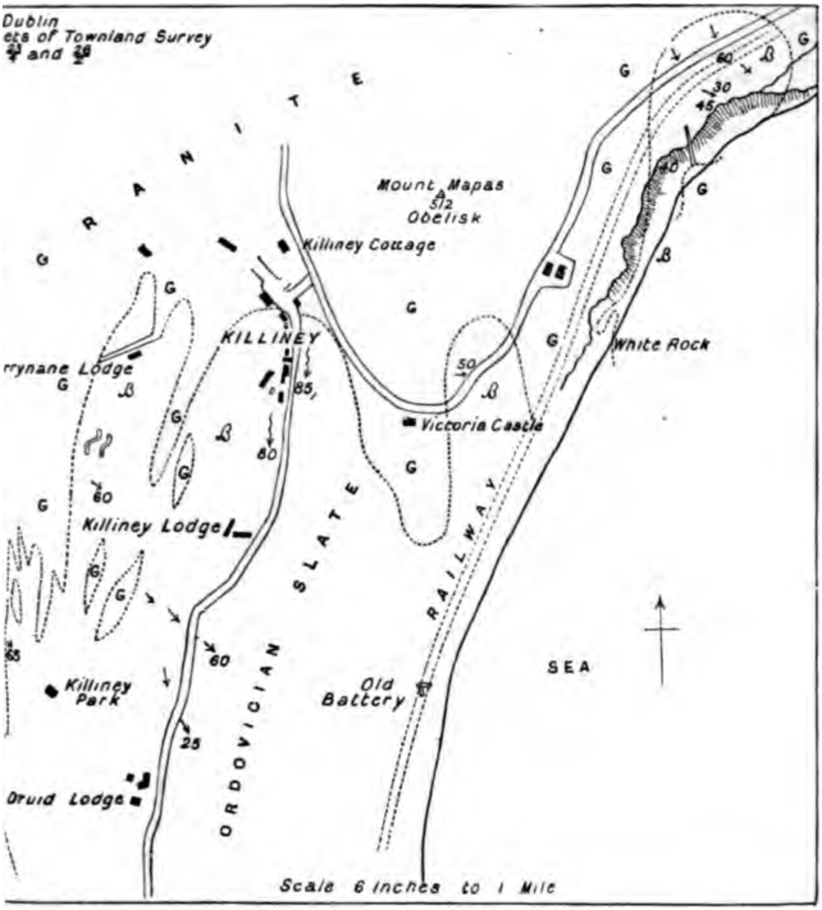
The fluidity of the granite at the time of its intrusion is attested not only by the numerous veins or dykes which it sends into the surrounding strata but by the great scholls or flakes of Ordovician schists which it includes and which have evidently separated from the mass of the cover to be engulfed in the fluid magma.

The Consolidation of the Granite.—The progress of consolidation can be traced step by step: the first constituents to crystallise out were minute zircons and apatites, which appeared in vast numbers, floating like a fine dust in the molten material, and serving as nuclei about which black mica (*Haughtonite*) subsequently formed. Immediately surrounding the zircons the biotite is far more highly pleochroic than elsewhere, pointing to the presence of an excess of iron in the first deposited molecules of the biotite: after its formation the biotite was greatly corroded by the magma, the products of the decomposition contributing to the material of the next mineral to extricate itself, that is muscovite. After the muscovite followed lime-soda- and soda-lime-felspar crystals, and finally the potash-felspar, microcline, and quartz. Of these last two one or the other crystallised out first according to circumstances and sometimes both appeared together.

It will be observed that the order of consolidation:—zircon, apatite, biotite, muscovite, lime-soda, soda-lime felspar, quartz and microcline is also the order of specific gravity of the minerals, the denser being the earlier to appear; and further it will be noticed that on the whole the order is one of increasing acidity.

It is interesting to consider the order of consolidation of the constituents of the granite in connection with the movements to which it was subject: thus if it were in a state of flow before any crystals had formed, and ceased to flow directly they commenced to appear, then very few indications of its movement would be preserved, but if it had already reached the stage at which the micas had consolidated, then we should find the plate-like crystals of these minerals lying with their flat faces in parallel lines concordant with the direction of streaming, while the succeeding minerals would present no signs of arrangement. A perfect example of such a case is to be seen in a small quarry close to the garden wall of Killiney Park, on the flank of Roche's Hill (Fig. 13). Naturally, if the magma continued to move after the felspars had consolidated a general fluxional structure would be produced, and of this I believe instances are not wanting.

FIG. 12.—MAP OF THE GRANITE AND MICA-SCHIST AT KILLINEY (*Geological Survey of Ireland*).



G. Granite. B. Mica-schist (altered Ordovician).

Returning to the swelling dome of Ordovician grits and slates and the fluid granite rising within it we may proceed to enquire further into the interaction between these two mountain-making factors: we have seen that the lake of granite leaked into the fissures of its surrounding walls, and thus led to the formation of dykes, while fragments of the walls broke off and fell into the lake. The inner surface of the Ordovician dome—judging from the granite, which we may regard as its cast, more or less defaced by denudation—must have had a length of sixty miles, a maximum span of seventeen miles, and a height, at least in places, of 3,000 feet. It is difficult to understand by what means such an arch could exist, unless it derived a large share of its support from the granite it enclosed. Again if the whole of the granite in its present position existed at any one time in a completely fluid state, far more numerous dykes than are really known to occur might be expected to penetrate the Ordovician cover, since disregarding any pressure which the cover alone might exert, that of a column of fluid granite 3,000 feet in height would amount to at least 200 atmospheres.

FIG. 13.—BANDED GRANITE, NORTH OF THE GARDEN WALL OF KILLINEY PARK.

(From the *Memoir of the Geological Survey*, to accompany Sheets 102 and 112, p. 33)

Considering this, the comparative paucity of dykes is sometimes somewhat surprising.

The difficulty, however, arises from the unnecessary supposition that the granite was once entirely fluid while in its present position : for since it was, in all probability injected, not all at once, but in successive sheets, there is at least the possibility that the earliest flows might have had time to cool and harden sufficiently to afford protection against succeeding ones. At the same time whatever joints or cracks were produced during the cooling of the earlier sheets would be healed up by injections from subsequent ones, and thus the so-called "contemporary" dykes would arise (Fig. 14).

Sufficient mass however must be accorded to the first injected sheets to explain the great mineral alteration they have effected in the covering Ordovician rocks, for these are more or less metamorphosed for a very considerable distance from their junction with the granite, not infrequently for one or two miles: though this extreme extension of the metamorphosed area may find its explanation in a corresponding but concealed extension of the granite sheet beneath the area. The mineral change commences with the development of mica along the cleavage planes of the slate, which thus acquires additional lustre. As it progresses brown mica is developed in larger quantities till a genuine mica-

FIG. 14.—EURITE DYKE, ENCLOSING ANGULAR FRAGMENTS OF THE ADJOINING GRANITE: RAILWAY CUTTING, N. SIDE OF KILLINEY TUNNEL.

(From the *Memoir of the Geological Survey*, to accompany Sheets 102 and 112, p. 29.)

schist results: at the same time other minerals are produced, such as garnets, which appear in great numbers, giving us a garnet-mica-schist. Chiastolite, andalusite and fibrolite successively appear; and whatever quartz silt was originally present is converted into a quartz mosaic containing abundant vapour cavities. The nature of the change produced evidently depended on the nature of the sedimentary material originally present, and thus the bedded structure is preserved in the schists. The alteration evidently commenced before the tangential pressure of the rising dome had made itself fully felt, a fact completely in accord with the view that the granite was injected *pari passu* with the folding of the cover. As the tangential pressure and the movements of the Ordovician rocks became more pronounced marked effects followed in the already metamorphosed schists. Thus the mica and other constituents which run parallel with the schistosity, deviate from it on each side of resistant crystals, such as garnets, as though following stream lines, while the garnets themselves are cracked across in planes at right angles to the foliation. The cracks in the garnets extend into the surrounding quartz mosaics, when these are present, being then represented by planes of vapour cavities. In this connection, however, it is to be observed that a second set of vapour cavities running in planes parallel to the foliation and therefore at right angles to the preceding is usually present in the quartz: the two sets of planes occur together, one cutting across the other without either suffering any displacement. No second set of cracks however traverses the garnets in correspondence to the second set in the quartz mosaics.

The pressure which thus modified the structure of the metamorphic schists at the same time affected the granite, converting it about its junction with the schists more or less completely into gneiss. As the constituents of the gneiss are the same as those of the granite and have consolidated in the same order, the only distinctive difference is the presence of foliation in the gneiss, and this can be shown by microscopic examination to be due to the crushing of the quartz and the internal shearing of the whole rock along numerous gently undulating and intersecting surfaces (Fig. 15) which correspond to the planes of foliation.*

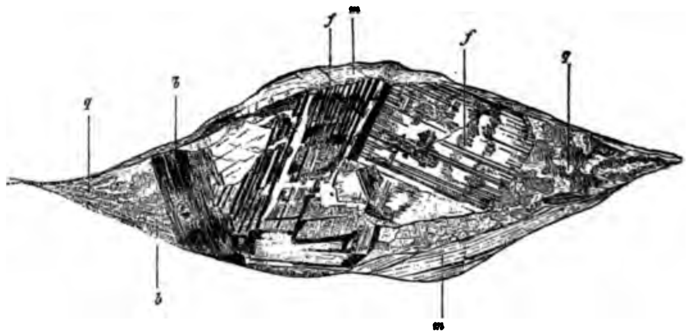


FIG. 15.—A SINGLE PHACOID OF GNEISSOSE GRANITE FROM ANN'S MOUNT, DUBLIN. (× 5 DIAM.)

In crushed granite numerous undulating and intersecting planes of shearing frequently divide the rock into more or less lenticular fragments called by Lapworth "phacoids."

* One of the earliest observers of the effects of pressure on the granite is certainly the Rev. Prof. Haughton, whose collection of triboliths in Trinity College Museum (still one of the most interesting in Britain) shows how far he had pushed his researches in this direction.

The foliation of the granite was evidently produced after its complete solidification, and affords strong presumptive evidence of the continuance of the upward movement of the Ordovician dome subsequent to its intrusion, and hence of the additional injection of fluid granite subsequent to the consolidation of the first intruded sheets.

Lying parallel to the margin of the great granite laccolite are numerous smaller intrusions of a more basic granite, which however do not belong to our area, since the nearest is to be found at Aughrim, thirty-five miles from Dublin. These are evidently of later date than the main chain, they do not exhibit foliation at the margin, and the contiguous Ordovician slates have undergone no foliation since their formation. Chiastolite has developed in them, but without obliterating their planes of cleavage. It is near Seven Churches, in the Vale of Glendalough, and therefore within our area, that the metamorphosis of the Ordovician slates by the granite may be best observed, and the same locality affords a further instance of metamorphism of a very remarkable kind. A mass of very basic rock, showing spheroidal jointing and consisting chiefly of pyroxene and hornblende, a true amphibolite, has penetrated the Ordovician schists a little to the east of their junction with the granite: the effect of this upon the schists has been to destroy nearly all traces of their foliation, soldering them together into a massive rock known as desmosite, which consists chiefly of garnets, with some quartz and biotite. The biotite is small in quantity and though it still lies in the original planes of foliation the flat faces of its crystals are turned round so as to lie almost at right angles to their original position.

From its effect on the mica schists this amphibolite would clearly appear to have been injected subsequent to their metamorphism by the granite and so to be the more recent rock of the two.

But the real interest of this rock consists in the transformation, which it has itself suffered near its junction with the schists. The granite shows no signs of having been modified, so far as its mineral composition is concerned, by its boundary walls, but the amphibolite has become converted into a wholly different rock: silica has penetrated it in solution from without; in consequence the hornblende becomes first actinolitic, and then passes into biotite, felspar has developed, and quartz has crystallised out in mosaics. From an amphibolite the rock has become a quartz-mica-diorite. In the adjacent schists quartz veins are numerous, in some places bearing valuable copper and lead ores, so that thermal waters and hot springs would seem to have completed the last chapter in the history of the igneous activity of the district. But some of the quartz veins occur so close to the amphibolite that one cannot refrain from supposing that the water which formed them flowed also through the amphibolite and brought about its metamorphosis by a true metasomatic action.

The supposition can scarcely be avoided that the contemporary volcanic ejectamenta of the Ordovician system were in some way connected with the same magma basin as that which supplied the granite laccolite, though their remarkably diverse nature, ranging from basalt to liparite, stands in marked contrast to the uniform composition of the granite. One may fancy one sees in them the first products of long previously differentiated magmas lying deep below the surface, that became mingled in confusion during the first uprush into a newly formed cistern: while in the granite one seems to discover the upper layers of the cistern, that were not squeezed out till a fresh settling of the contents had separated the lighter from the heavier magma.

The folded Ordovician rocks, with their granitic core, remained above the sea level during the whole of the Silurian and probably Devonian period also: a vast interval, during which they were exposed to all the ravages of denuding agents: rain and rivers removed much of the cover from the granitic laccolite, and revealed the granite to the light of day, the buried Cambrian rocks were also in many places laid bare, and a country resulted where splintered crests of slate rose surmounting, and bordering a lofty mountain range of granite, which was warded on the north by one or more massives of Cambrian :—still standing pillars of a great system, which else for the greater part had sunk down into the depths of the earth. This land of the Leinster Alps formed but a part of a much wider territory, which probably included St. George's Channel and the then youthful hills of Wales: that it was mantled over with the Cryptogams of the time and afforded a theatre for the great drama of animal existence one can hardly refuse to imagine, but whatever forms of life then peopled it, all, unsubstantial as visions, have disappeared and the palæontological record retains no trace of them.

That this apparently firmly established land with its "eternal" mountains should slowly but surely subside beneath the waters of the sea would seem a dreamer's fancy, did we not know it for sober truth. At the commencement of Carboniferous times we find Leinster and Wales united across the Channel as an island, which we may name St. George's Island, and its beaches, which were then dragged to and fro by the surrounding waves are preserved for us in the conglomerates of Portraine and Lambay Island. These consist of pebbles of reddish quartzite and white vein-quartz, which have been derived from Cambrian rocks, precisely similar to those which form the peninsula of Howth. As the island continued to sink beaches were formed at higher and higher levels along its flanks, so that at Skerries a deposit of pebbles and boulders of Ordovician grits and diabase is met with high up in the Carboniferous limestone series; and in the Calp, a black earthy limestone which is supposed to occur about the middle of this series, angular and rounded fragments of Leinster granite, some as much as 8 inches in diameter, are not infrequently found associated with bits of Ordovician schist. They afford incontrovertible proof of the exposure at this time of the granite from beneath its cover. Jukes has suggested that these granite fragments may have been carried into the place where they are now found by trees in whose roots they were embedded, in the same manner as stones are known to be floated to coral islands at the present day, but Prof. V. Ball thinks it more likely that they were carried by attached seaweeds which had grown upon them.

The depression of St. George's Island probably continued till it was wholly submerged beneath the sea, and buried up beneath the entire Carboniferous system: sheets of coal-measures forming the highest deposits, which stretched in one wide plain over the greater part of the British Isles. In parts of England the Carboniferous strata present a thickness of 20,000 feet, near Dublin they probably did not attain one-fifth of this, but the time which elapsed during deposition was probably the same in both cases, that which differed was the rate of subsidence of the sea floor, and consequently of sedimentation.

The downward movement of the land which rendered the deposition of sediment possible at length came to an end, and was reversed, an upward movement commencing, which ushered in one of the most pronounced periods of great mountain building that the earth has ever experienced: the great Hercynian zone of foldings which resulted rivalling at the time both in altitude and extent those later ones which now form the mighty Alpine-Himalayan chains. In our district the effects are seen in a system of synclinals, that commences from the Ordovician exposure at Balbriggan, and runs more or less concentrically with the end of the granitic chain towards the Chair of Kildare: in the country intervening between this system and the granite we should expect to find a generally domed area having its centre near Donabate, and such is clearly discernible; south of this however the structure of the area is puzzling and obscure. Interesting features of detail are the foldings, overfolds, and overthrusts in the Carboniferous rocks near Loughshinny, and the vertical position they assume nearer Rush, still more the position of the red basal conglomerate on Lambay Island, where it occurs unconformably lying on the Ordovician rocks, but at the same time folded and faulted with them in a manner which cannot fail to impress us with the extent to which the pre carboniferous land must have shared in the post-carboniferous movements. Another instance of the effect of these movements on Ordovician rocks is to be observed at Glendalough, where the mica-schists wrinkled in post-ordovician times in a direction parallel to their junction with the granite were again wrinkled in post-carboniferous times in a direction transverse to the previous one.

Probably the majority of the post-carboniferous flexures were determined by those already produced in post-ordovician times, as these were by others which preceded them in post-cambrian times.* One set of ancient lines of weakness runs from east to west through the midst of our district, and may be indirectly responsible for the existence of Dublin itself; it corresponds to the northern limit of the granite, and of the Cambrian rocks of Howth and Ireland's Eye, which are both bounded on the north by a steep east to west coast line; traced westwards the yielding band corresponds to the general synclinal depression which divides Ireland into a northern and southern moiety, and in the extreme west it determines the straight east to west coast-line which bounds the south of Galway: in the middle of its course, near Tullamore, are igneous rocks, which would appear to have been pressed up along it. Traced eastward, it marks the north coast of Anglesey and Wales, and then is lost beneath the Trias plains of Cheshire; but parallel lines of disturbance continue its direction, the Dane anti-clinal and the sharp east-to-west southern limit of the Pennine chain, which passing eastwards determines the V-shaped flexure of the Mesozoic outcrops, and the northern boundary of East Anglia.

The post-carboniferous is the last of the mountain building periods which have left any evident trace in our district; the land then produced seems to have remained above the sea level during the whole of the Mesozoic and Tertiary periods; suggestions of the presence of an arm of a Triassic lake are to be found in the dolomitisation of some patches of the Carboniferous limestone, as near the south side of Sutton on Howth and elsewhere; but since the British Triassic lakes probably lay above the sea level, this does not involve any submergence. The long-continued existence of a large tract of land during the Jurassic period to the west of the English sea is suggested by many considerations; and of this, our district probably formed a part, contributing its share to the Jurassic sediments. Possibly here were the sources of some of the tributaries to the great Wealden river, tributaries of which, indeed, our existing rivers may be the lineal descendants.

Whether the margin of the Cretaceous sea ever passed over our area must remain in the highest degree doubtful. Fragments of chalk-flints are common enough in the local glacial deposits, and by some are regarded as remanié, left more or less *in sitû*, but the evidence for a submergence must be based on surer proofs than this, since numerous foreign rocks in our glacial drift can be traced to a home in the north of Ireland, where chalk-flints are still to be seen embedded in the parent chalk. If ever,

* See Bertrand: "Sur la Continuité du Phénomène de Plissement," *Bul. Soc. Géol. France* sér. 3, tom. xx, p. 118.

since the Palæozoic æra, a plain of marine denudation was cut across Ireland it might well have been during the Cretaceous period.

During the enormous lapse of time included in the Mesozoic and Cainozoic æras the sculpturing of our land, which had already, during the Siluro-Devonian period, been partially blocked out into shape, had ample time for its accomplishment. The existing rivers were probably initiated in Carboniferous rocks, which have since suffered excessive denudation, and in all that part of the district which lies south of Blackrock have been completely carried away, exposing the post-ordovician land once again to the light of day. Since the land on which our rivers originated has thus disappeared it might be thought a useless task to attempt to account for the vagaries of their windings, were it not that the foldings of newer rocks are so frequently but a renewal of previously existing ones. True, as it may be, that the Carboniferous rocks passed right over the highest summits of the granite range of Leinster, yet this range was by no means obliterated, but on the contrary still maintained its just pre-eminence, conferring upon the Carboniferous surface a slope not altogether unlike that which it now presents itself. Hence we may not without hope seek to explain the course of some of the rivers of our district, of which the most remarkable is the Liffey: broadly looked at the first part of the course of the Liffey is down the western side of the granite range and over the onlying Ordovician rocks due westwards towards the basin of the Barrow, of which it scarcely escapes forming a tributary, a fate from which it is saved by an anticlinal of Carboniferous limestone rising athwart its path: this turns it quickly round to the right, so that from Kilcullen to Clane it pursues on the whole a northerly course. Then it begins to turn round towards the east, and from Lucan till it enters Dublin Bay its direction is due east, or exactly opposite to that with which it started. This part of its path was evidently determined like the rest, by the slope of the Carboniferous land, the eastern inclination of which is indicated by the direction of all the rivers which discharge into the Irish Sea from the Slaney on the south to the Dee and the Fane which open into Dundalk Bay on the north.

The river systems initiated on the Carboniferous slopes, as they sank downwards, encountered the pre-carboniferous rocks, and these they sawed through without changing their direction, being held to their existing channels by the Carboniferous "training walls": hence many of our rivers flowing through hard rocks have produced picturesque ravines with steep rocky sides, such as The Glen of the Downs, The Devil's Glen, The Scalp, and The Dargle. The Carboniferous scaffolding having since been removed, the rate of excavation of a river through a hard rock has sometimes proved so slow, that an independent stream, working more rapidly, has cut across its course and tapped it above its ravine which thus despoiled of its river now remains as a nearly dry notch, "a scratch made by the toe nail of the giant Finn Mac Coul": an instance of this is the Scalp.

Through the long æras of the Mesozoic and Tertiary our district, as we have seen, formed elevated land, our mountains were sculptured into form, and our valley systems excavated by the power of rain and rivers. Of contemporaneous deposition there is no trace; whatever sediment was produced was carried out of the district and laid down elsewhere; but when we leave the Tertiary and pass into what we may be excused for calling Quaternary times, we discover a remarkable series of deposits, the interpretation of which is as yet only half complete. These are the glacial drifts, which are scattered broadcast and, as it were, at random over our area. Beneath these deposits the underlying rock, when freshly exposed, presents the most beautifully smoothed, polished, and striated surface; the direction of the striæ, as shown by the Rev. Maxwell Close (Fig. 16), usually running with great constancy over wide areas from W.N.W. to E.S.E.; over the whole of Howth, for instance, this direction is maintained with a deviation of only a few degrees; south of Killiney, as at Ballycorus, Carrickgologan, and Bray, the direction changes, and occasionally becomes nearly due N. and S. In addition well-preserved roches moutonnées are frequently encountered, as on the granite near Killiney and the Cambrian quartzite at Howth. The evidence is unmistakable and the conclusion obvious; the whole of the district previous to the deposition of the boulder clay must have been overridden by the ice of glaciers, which from other evidence we know to have formed part of a great *mer de glace* which buried the whole of Ireland, perhaps with the exception of some few high peaks, completely out of sight. In our area the movement of the ice was, as shown by the striæ, approximately from the north-west.

The deposit usually overlying the glaciated surface is Lower Boulder Clay—a stiff clay, containing numerous subangular glaciated boulders, which most commonly consist of mountain limestone; but in addition angular fragments, and even rounded pebbles, are met with, and that not infrequently. The study of these included stones has not as yet been carried far, but my friend Mr. Pomeroy, of Trinity College, who is engaged with me in investigating them, has kindly permitted me to make use of such preliminary results as we have obtained. In some cases the witness of the pebbles corresponds with that of the striæ, as, for instance, in the remarkable deposits of the Cookstown river, where we find, in addition to rocks derived from the river basin, others which must have been brought from the west, right over the granite range, such as mountain limestone in great quantity, diabase, such as occurs at Bohernabreena, and red conglomerate like that at Newcastle; but along the sea coast there is every

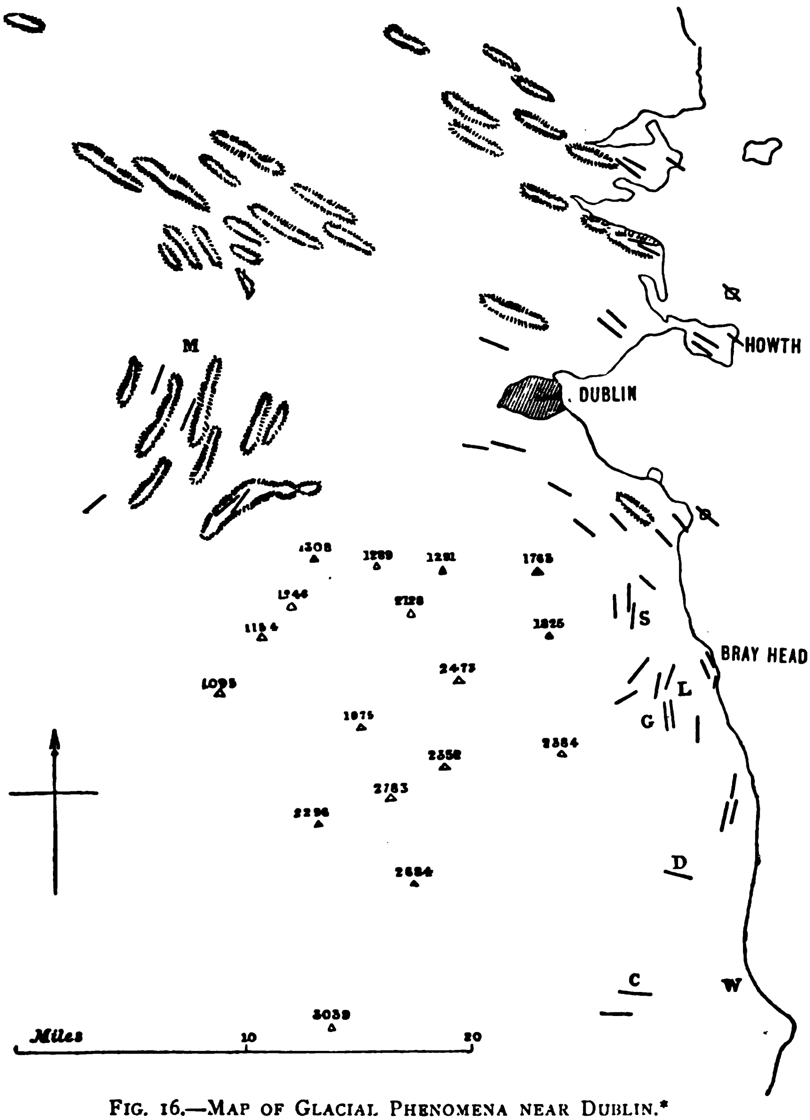


FIG. 16.—MAP OF GLACIAL PHENOMENA NEAR DUBLIN.*

The short strokes give the directions of the rock-striations. The ridges represent diagramatically the distribution of drumlins.

S, Summit of Shankhill, 912 feet; G, of the Great Sugar Loaf, 1,659 feet; L, of the Little Sugar Loaf, 1,120 feet; D, of Dunran Hill, 1,122 feet; C, of Carrick, 1,252 feet. M, Maynooth; W, Wicklow; T, Trim.

* By the Rev. Maxwell H. Close, *Proc. Roy. Geol. Soc. Ireland*, vol. i, p. 3, 1867.

evidence of travel from the north, while the striæ point to movement from the north-west. Thus we find between Howth and Balbriggan, and on Lambay Island, fragments of a characteristic red syenite, with well-shaped green crystals of hornblende, that can be identified with a rock *in situ* near Fairhead, boulders of Mourne mountain granite, sometimes 2 or 3 feet in diameter, of anorthite gabbro from Carlingford mountain, blocks of rhyolite from the hills of Carrickbroad and Forkhill near Sleive Gullion, abundant fragments of granophyre from the Mourne mountain district, a good deal of granite that we have not yet identified, possibly Scotch, and riebeckite granophyre like that of Ailsa Crag, the occurrence of which at Killiney and Greenore has already been signalised by Professor Cole. This last rock, which usually occurs in the form of rounded pebbles, is far from uncommon, but it has yet to be proved that it does not occur *in situ* in the Mourne district.

Signs of stratification, not to be confused with striated pavements, are certainly far from absent from the lower Boulder Clay. Trains of boulders and layers of pebbles can be seen in it at various localities, most obviously in the cliffs of Howth, and it passes upwards into the well-rounded, false-bedded sands and gravels known as the Middle Glacial Drift. That it is the undoubted product of the ice which scored and polished the underlying rocks no one, probably, will be found to deny; but that the sea had no part in its formation would be a very bold assertion, and the problem would seem rather to be to determine to what extent and exactly in what manner marine action was involved. That the glacier-ice continued to flow during or after the deposition of the Boulder Clay, in the same direction as it did when it striated the rocks, is plainly shown by Mr. Close's discovery of long, rounded ridges of Boulder Clay, or "drumlins," which run parallel to one another and in precisely the same direction as the rock striæ (Fig. 16).

The middle glacial sands and gravels, which are well seen at Howth, attain a very considerable thickness, and not uncommonly contain marine shells, usually in a fragmentary condition. The following were identified by Dr. Scouler, from Howth: *Turritella communis*, *Littorina littorea*, *L. littoralis*, *Buccinum undatum*, *Cardium edule*, *Cyprina islandica*, *Pecten varius*. Stratified sands and gravels which may belong to this middle drift, and which resemble the well-known deposits of Moel Tryfaen, have been found by Mr. Close in several localities at elevations of 1,000 feet and more; near Caldbeck Castle, on Kilmashogue Mountain, at an elevation of over 1,200 feet, they yielded the following species: *Cardium echinatum*, *Cyprina islandica*, *Venus striatula*, *Mactra stultorum*; and at Ballyedmunduff, on the S.E. side of Three Rock Mountain, at an elevation of 1,000 feet, the following were obtained: *Trophon muricatus*, *Turritella communis, Ostrea edulis, Cardium edule, C. echinatum, Astarte compressa, A. elliptica, A. sulcata, Cyprina islandica, Artemis lincta, Venus striatula, V. casina, Lutraria elliptica, Pholas crispata, Balanus balanoides.*

Mr. Close suggests that much of the middle drift may have been derived from the boulder clay, and that in some instances it has been washed down from higher ground than it now occupies. Great probability attaches to this suggestion : the pebbles of the sands are as foreign to the district in which they occur as the boulders of the boulder clay, which may not only have furnished these but also many of the shelly fragments. Shells are certainly not wholly absent from the boulder clay, they may be obtained from it in the coast sections between Skerries and Balbriggan, whence Mr. Gaffney, of Trinity College, obtained a *Leda* with both valves entire. A view now fashionable sees in the shell-bearing high-level drifts, flakes of the sea-bottom that have been carried bodily away by glaciers, which have climbed from the sea-level over our hills ; however this may be, it is worth pointing out that many of our shelly drifts lie in the course of glacier-ice, which so far as we can determine never passed over any existing sea floor, but flowed wholly on the land. This is an objection which seems to me worthy of consideration : it can of course be met, if we wish to retain the lifting of sea bottoms in the recognised programme of glacial gymnastics, by asserting that a pre-glacial depression had distributed marine deposits over much of what is now dry land, and that the high level drifts have been pushed up from these. But there are difficulties in the way of this explanation.

The Middle Drift passes into the Upper Boulder Clay, which is of a looser texture than the Lower, presenting like it traces of stratification. It is followed by those most remarkable accumulations of false-bedded sands and gravels, heaped in mounds and long-winding ridges, known as Eskers. One of these, a ridge three miles long, and from 35 to 60 feet high, occurs at Greenhills, a few miles out of Dublin, another at Esker near Lucan. The legend associated with some natural features, of their being ropes of sand, made as a penance by one of the innumerable forms of Satan, would apply fittingly to this, which looks as artificial as a railway embankment. The explanations which have been offered of the formation of these eskers, kames, or osars, as they are variously called, are as numerous as they are unsatisfactory ; that they were formed before the final close of the glacial epoch is rendered clear by the occurrence of large erratic blocks which rest upon them, and that they were deposited by rapidly moving water is equally certain ; at present perhaps the suggestion of the American geologists, Lewis, Stone, and Wright, that they represent the gravels of the superior, interior, and perhaps inferior streams of glaciers meets with fewest objections.

The last glacial deposits in our area are valley moraines, some of which occur as dams to small mountain lakes, like those of the Upper and Lower Loughs Bray; and apron moraine matter, which is strewn far and wide over the high ground (800 to 900 feet) at the foot of the granite range; some of the scattered blocks of granite are of stupendous size, one near Roundwood is as large as the little cottage which stands by its side.

Judging by the submerged peat which is found on the Irish coast, but not within our area, the land stood somewhat higher than it does now at the close of the glacial episode, but it was certainly subsequently depressed, and the last movement was one of emergence, as is shown by the well preserved raised beaches on Lambay, Ireland's Eye, and round the coast at Malahide, where oyster beds still *in situ* may be seen considerably above the level of low tide. At Ireland's Eye, at about 13 feet above the sea-level, is the remains of a sea beach with shells, abutting against an old sea cliff. Indications of raised beaches at considerably higher levels are to be met with round the Irish coast, some at an elevation of 300 feet—on Lambay there seem to be indications of such an one; but whether these are post-glacial in age cannot be regarded as definitely ascertained.

To attempt in the present state of our knowledge to give a connected account of the history of the district during the glacial period would be an unprofitable, if not an impossible task. All that we certainly know is that in times comparatively recent the land was almost, or perhaps altogether, buried under the moving ice of great confluent glaciers, which smoothed, polished and striated its surface; that under this ice, possibly then buoyed up by the sea, thick sheets of boulder clay were deposited, that the conditions which produced the boulder clay were modified or passed away, and vast accumulations of stratified sand and gravel, containing fragments of marine shells, were laid down over it; that again during the formation of the upper boulder clay conditions similar to those which produced the lower boulder clay recurred, to again disappear; and finally as they passed away, and the confluent ice-sheet resolved itself into local glaciers, morainic fragments were left stranded over the face of the country, and valley moraines were piled up across the retreating termination of the dwindled valley glaciers, which nestled in the recesses of our hills. Changes of sea-level probably accompanied the waning and waxing of the ice, but since the advent of man the relative level of land and sea would appear to have remained almost, though not quite, unchanged. Of the geological changes, which have since proceeded, the delta formations in our loughs, such as that at the head of the upper Lake of Glendalough, and that which divides the upper from the lower lake in the same glen, may be cited, as well as the blown sand which forms extensive dunes along the coast north of Malahide.

Of remains of man himself few traces are preserved, but an interesting camp, probably of the bronze age, is open to investigation on Howth Head. A rampart-like mound faced by a fosse protects this from attack from the mainland. On the flat behind it are found the remains of hearths sunk into the gravel, which, to the depth of a few feet, forms the ground. Charcoal, bones of sheep, pig, oxen, deer, shells of limpets, periwinkles, cockles, and oysters are found in great abundance associated with the hearths, but particularly in the sloping sides of the southern cliff, which is a very kitchen-midden. Remains of the common seal, fragments of copper slag, and a bone marrow scoop have been found in this place. The staple food of the village would seem to have been limpets, the quantity of limpet shells left behind is prodigious.

Here we approach the dawn of history, and our task as geologists is finished. May it be fittingly crowned when we visit Howth Head by a modern lunch and a prehistoric appetite!

EXPLANATION TO PLATE III.

FIG. 1.—Section of Quartzite from Carrickgologan. This is taken from a typical Quartzite "horst," but retains its original structure more perfectly than is frequently the case, the rounded forms of the grains being particularly well displayed. Photographed under the microscope (× 45).

FIG. 2.—The same section, but seen with polarised light. On comparing this with the preceding, the same grains can be identified, but many of them will be seen to be crushed almost out of recognition, while others show granulation at the margin. Photographed under the microscope (× 45).

REFERENCES.

Geological Survey Maps, Ireland, Sheets 102, 112, 121, and 130. The newer copies of the Ordnance Survey Sheets are preferable for walking excursions, and should be ordered "hill-shaded."

Memoirs of the Geological Survey of Ireland; to accompany Sheets 102 and 112 (Dublin area), to accompany Sheets 121 and 130 (Bray and Wicklow).

References to most of the geological literature on Co. Dublin will be found in five illustrated papers entitled, "Co. Dublin, Past and Present," by Prof. Cole in *The Irish Naturalist* for 1892. Copies of volume i, containing these papers can be obtained from Messrs. Eason and Son, 40, Lower Sackville Street, Dublin.

1819. WEAVER, T.—"Memoir on the Geological Relations of the East of Ireland." *Trans. Geol. Soc. London*, 1st ser., vol. v. [Effective panoramas of the scenery.]

1859. JUKES, J. B., and HAUGHTON, S.—"The Lower Palæozoic Rocks of the South-east of Ireland."

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1878. CLOSE, MAXWELL H.—"The Physical Geology of the Neighbourhood of Dublin." *Journ. Royal Geol. Soc. Ireland*, vol. v, p. 49. [With illustrations and a coloured map.]

1878. BAILY, W. H.—"On the Palæontology of County Dublin." *Ibid*, p. 78. [The part containing the above two papers (vol. v, pt. i.) can be obtained from Messrs. Hodges and Figgis, Grafton Street, Dublin. Price 2/6, post free.]

1887. KINAHAN, G. H.—"Oldhamia." *Journ. Royal Geol. Soc., Ireland*, vol. vii, p. 166. [Good account of localities of this fossil.]

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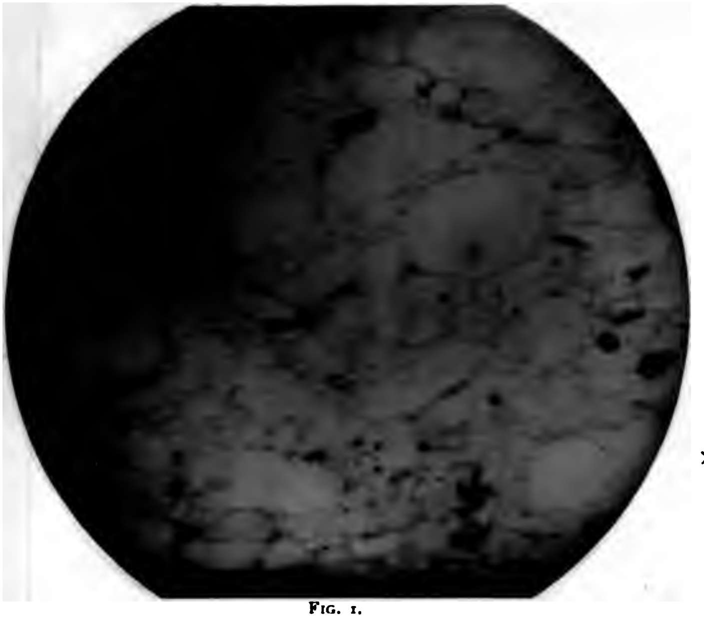
1891. ———— "Contributions to a Knowledge of the Granites of Leinster." *Trans. Royal Irish Acad.*, vol. xxix, p. 427 (part xiv).

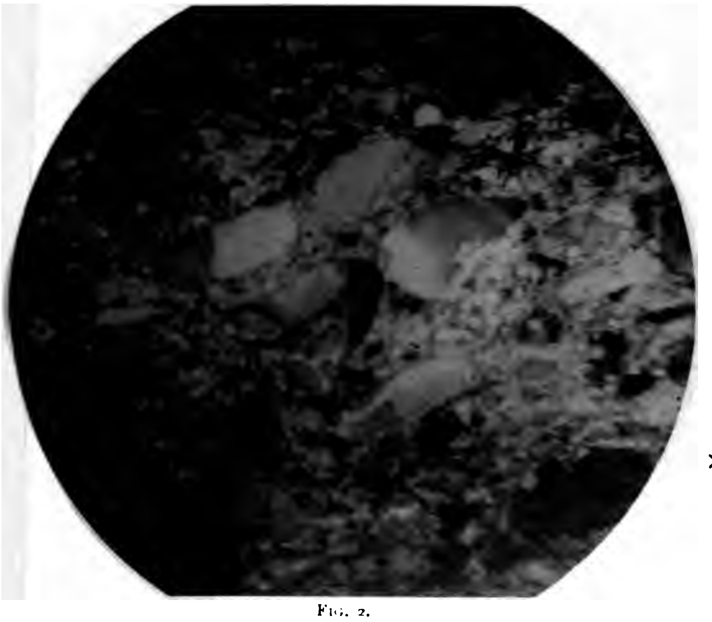
1891. ———— "On the Structure and Origin of the Quartzite Rocks in the Neighbourhood of Dublin." *Proc. Royal Dublin Soc.*, vol. vii, p. 169.

1893. ———— "On the Variolite and Associated Igneous Rocks of Roundwood, co. Wicklow." *Proc. Royal Dublin Soc.*, vol. viii, p. 94.



× 45.

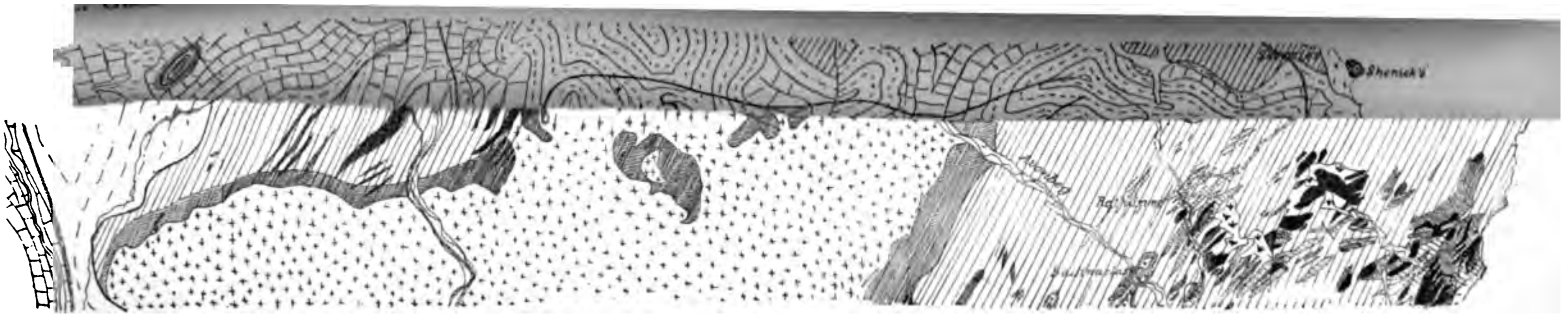
FIG. 1.



× 45.

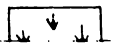
FIG. 2.

QUARTZITE CARRICKGOLOGAN.



GEOLOGICAL MAP OF DUBLIN AND NEIGHBOURHOOD.

Scale—1 inch = 5 miles.



Bog.

EXCURSION TO AMWELL AND CHADWELL SPRINGS.

SATURDAY, 6TH MAY, 1893.

Directors: JOSEPH FRANCIS, M.Inst.C.E., and W. TOPLEY, F.R.S.

(*Report by* W. TOPLEY.)

THE main object of this excursion was to examine the head-waters of the New River Company, and the sites of some of the wells.

Leaving the train at St. Margaret's, the party walked S.W. to the pumping station at Rye Common. Close by is seen an abandoned channel of the New River, this being one of the numerous places at which the course of the original artificial channel has been shortened. Walking N., along the bank of the New River, the party passed the sites of the pumping stations at Amwell Marsh and at Amwell Hill, and of the Amwell Spring, which lies between these two wells. Continuing the walk past Amwell End Well, a halt was made at the Broad Mead Well; this is perhaps better known as the Ware Boring. A shallow well has been sunk into the Chalk (gravel, etc., 17 feet, Chalk 9 feet) and a boring made through the Chalk, Upper Greensand, and Gault into the Palæozoic rocks.

The section of the well and boring is as follows (in feet):—

	Thickness.	Depth from surface.
Gravel	16	
Chalk	542	558
Upper Greensand	77	635
Gault	160	795
Wenlock Shale and Limestone . .	36	831

Too great a thickness is here given to the "Upper Greensand." It probably includes the lowest beds of the Chalk.

A good number of cores are still preserved from the lower parts of the Chalk, the Upper Greensand, and the Gault. Many specimens and a fair number of fossils were taken by the members.

Continuing the walk westwards the party inspected Chadwell Spring, the original source of the New River; then walked north across the meadows to the "intake" of the New River from the Lea. Having now finished our programme, the walk was continued up the Lea to Hertford.

OCTOBER, 1893.

The New River Company had kindly given permission to inspect all the works, and explanations were given by Mr. Francis, the chief engineer of the Company.

The "New River" was constructed by Sir Hugh Myddelton to bring water from the springs of Chadwell and Amwell to London. The works were completed in 1613. The length of the New River was originally forty miles, following the contour of the country, but by making cuts and aqueducts it has now been shortened to twenty-six miles. The whole flow of the Chadwell Spring is taken; but that at Amwell has yielded practically nothing to the New River for about 100 years, the spring now escaping at a lower level into the River Lea.

The New River is now also fed direct from the Lea at the intake by an automatic floating gauge, which allows 22½ million gallons daily to pass over it. During floods, when the water is very turbid, this is not taken.

The Company has in all thirteen wells in and near the Lea Valley, from which an average of nearly eight and a half million gallons was pumped daily in 1891. The yield of the Chadwell Spring varies much; its average daily flow in 1891 was 2,001,000 gallons; in 1884, a dry year, the daily average was 2,097,000, and in 1883 it amounted to 3,627,000 gallons.

The total population supplied in 1891 was 1,159,260, and the average daily quantity pumped was 32,641,000 gallons, or about 28·16 gallons per head. The water from the various wells, with two exceptions, is pumped into the New River, and all is then filtered before delivery. The Company's filter beds cover an area of 16½ acres.

The area of the River Lea above Feilde's Weir, where the Chalk passes under the Tertiary beds, is 422 square miles, which are grouped as follows:—

	Square Miles.
Bare Chalk	95
Chalk covered with permeable beds	50
" " " mixed beds	60
" " " impermeable beds	217
	422

These figures are taken from the Report of the Royal Commission on Metropolitan Water Supply, 1893.

The mean annual rainfall over the area is 26·5 inches; the average fall of three consecutive dry years is 22·8 inches; and of the driest year 19 inches.

Diagrams were exhibited showing the monthly rainfall and percolation at Lea Bridge and Rothampstead; also the flow of the Lea and of Chadwell Spring.

The following table gives particulars of the wells visited during the excursion:—

	Feet.				In Feet above O.D.				
	Well.								
	To Chalk.	In Chalk.	Total.	Continued by boring to	Level of Surface.	Level at which Water stands when not pumping.	Level to which Water is pumped down.	Length of headings (in feet).	Average quantity pumped per day (million gallons).
Chadwell Spring	Chalk at Surface.				112	110	—		av. yield 3½
Wells :									
Broad Mead .	17	9	26	831	110	106	90	none	1½
Amwell End .	36	36	72	419	109	105	48	none	1½
Amwell Hill .	—	90	90	160	133	104	70	375	3¼
Amwell Marsh .	14	95	109	392	110	104	48	336	2¾
Rye Common .	19	185	204	none	110	94	3	371	3¾

The standing water-level of the Wells is approximately that of the River Lea near by. The quantity pumped is that taken from the several wells when required.

EXCURSION TO BATH, MIDFORD, AND DUNDRY HILL, IN SOMERSET, AND TO BRADFORD-ON-AVON AND WESTBURY, IN WILTSHIRE.

WHITSUNTIDE, 1893.

Directors: THE PRESIDENT (HORACE B. WOODWARD, F.G.S.), the REV. H. H. WINWOOD, M.A., F.G.S., W. H. WICKES, and EDWARD WILSON, F.G.S.

(*Report by* THE DIRECTORS.)

I. BATH AND MIDFORD.

Director: THE PRESIDENT.

THE Members of the Association have on previous occasions visited Bath: in 1872, under the guidance of Charles Moore and the Rev. H. H. Winwood, and in 1879 when Moore again acted as Director.* On no occasion however have the sections at

* Record of Excursions, pp. 345, 347.

Bradford-on-Avon and Westbury, and those of Midford and Dundry, been hitherto visited by the Association.

Early in the afternoon of Saturday, 20th May, the Members arrived at Bath, and the luggage being sent on to the Fernley Hotel, they started at once for Midford. Proceeding by Lyncombe, past the Abbey Cemetery, the ascent of Combe Down (522 feet) was made along Blind Lane. On the way a small section of the Fullers' Earth Rock (rubbly marl and limestone) was examined, and this yielded *Isocardia*, *Waldheimia ornithocephala*, etc. Higher up, the basement-beds of the Great Oolite were seen, and on top of the Down one of the freestone quarries was visited. Here from 9 to 10 feet of oolite is worked under the name of "Combe Down Stone." It is more or less wedge-bedded and in places minutely current-bedded, and some of the blocks are traversed by thin veins of calc-spar, but it is a good and durable freestone. To some extent it has been naturally seasoned, for it occurs near the surface on Combe Down, whereas in most places the Bath Stone is obtained by underground workings. Attention was drawn to the variability of the stone-beds, both in thickness and character, as they are traced from one locality to another. The freestone of Combe Down was overlaid by rag-beds and rubbly stone that are used for ashlar, road-metal, etc. Some of these layers are fossiliferous, and yield *Ostrea Sowerbyi*, *Pecten vagans*, *Rhynchonella concinna*, *Serpula*, *Apiocrinus*, etc. Sparry cavities are met with in the rocks, and these are sometimes due to the decomposition of Corals. Descending the hill, under the guidance of the Rev. H. H. Winwood, into Horsecombe Vale, attention was next drawn to a section of the Inferior Oolite and Midford Sands, shown in a cutting of the Midland (Somerset and Dorset) Railway. Passing on to Tucking Mill, a halt was made to see the tablet inserted in the dwelling-house (by Members of the Bath Natural History and Antiquarian Field Club) in memory of William Smith, "the Father of English Geology," who resided there in 1798-99, while he was engaged in the construction of the Somersetshire Coal Canal.

Through the kindness of Mr. Henry Newson Garrett (Proprietor of the Midford Fullers' Earth Works), the various processes undergone by the Fullers' Earth clay, to render it marketable, were examined and explained by the foreman. The raw earth is dug in the hill-side not far from the Cross Keys Inn, and it is conveyed in trucks down a steep incline to a "Pug mill." There it is ground up, with about three times its own bulk of water. The compound, known as "slurry," is then turned into a series of little tanks or "catch-pits," and while the fine Fullers' Earth remains in a state of suspension, the coarser particles sink to the bottom. The liquid, which still contains "impurities," is then allowed to run into a long earthenware drain, laid underground, which conveys it to the works, more than half-a-mile distant. Here the turbid water flows into a long shallow trough called a "maggie," and the coarser particles still contained in it then subside and are caught by a series of little wooden steps placed across the bottom of the trough. By these processes the Fullers' Earth is purified. It is now run into large tanks and the suspended earth is allowed to settle down gradually; while the surface-water that is drained off is said to be very soft, pure, and drinkable. These operations take about thirty days; and now a damp clayey mass remains in each tank. This material is removed to a large drying shed, where by means of a furnace and hot-air flues, it is thoroughly dried, and is then ready for market.*

The economic Fullers' Earth is from 4 to 7 feet thick, and is worked by means of galleries driven into the hill side. No good section of the overlying beds was to be seen, but they comprised blue and brown marly clays with bands of nodular earthy limestone. Among the fossils there occurred *Belemnites*, *Ceromya*, *Cypricardia*, *Waldheimia ornithocephala*, *Rhynchonella varians*, etc. Small nodules of limestone occur in the economic Fullers' Earth and these sometimes yield fossils. The Fullers' Earth is of a yellow colour at its outcrop, and blue underground; but there is no difference in the commercial value of the two varieties. Analyses of the earth had been made by Mr. J. Hort Player (details of which would be published in a Geological Survey Memoir); they showed that the peculiar detergent properties were due to physical characters and not to any special chemical composition, the earth not being plastic like ordinary clay, but falling to a powder under water. It was mentioned that a number of *Ostracoda* from the Fullers' Earth of Midford had been described by Prof. T. Rupert Jones and Mr. C. D. Sherborn.†

The Members now proceeded along the road near Midford Castle, to the road-cutting south of Midford railway-station. There the Inferior Oolite was again well seen, overlying the Midford Sands. It was pointed out that the Inferior Oolite belonged to the zone of *Ammonites Parkinsoni*, no traces of the lower zones of *A. Humphriesianus* and *A. Murchisonæ* having been observed. Thus there was locally a break between the Oolite and the underlying Midford Sands, which yielded *Ammonites radians*, *A. striatulus*, etc. Reference was made to Mr. S. S. Buckman's views on the palæontological zones in the Cotteswold, Midford, and Yeovil Sands;‡ and the Director maintained that the term Midford Sands was useful as a stratigraphical division that should include the Sands at those several localities. The Inferior Oolite at Midford yielded remains of *Lima pectiniformis*, *Trichites*, *Rhynchonella spinosa*, Corals, etc. Fossils were most abundant in

* These Notes are taken from an article printed in "Bladud," for 16th March, 1887. copies of which were kindly presented to the Members by Mr. Garrett.

† *Proc. Bath Nat. Hist. Field Club*, vol. vi. p. 249.

‡ *Quart. Journ. Geol. Soc.*, vol. xlv. p. 440.

the lower beds; and at the base, as pointed out by Mr. Winwood, there were pebbles of limestone, suggesting some reconstruction of the layers that marked the interval between the Midford Sands and Inferior Oolite at this locality. Casts and moulds of *Trigonia* were found in the higher beds of Inferior Oolite. Leaving this section the Members returned to Bath by train, and took a peep at the Roman Baths on their way to the Fernley Hotel.

In the course of the evening the President drew attention to some of the geologists who have made Bath famous. He first mentioned John Walcott, whose "Descriptions and Figures of Petrifactions, found in the quarries, gravel-pits, &c., near Bath," was published in 1779. Walcott then figured the fossils now known as *Apiocrinus Parkinsoni* and *Terebratula coarctata*. William Smith was more intimately associated with Somersetshire than with any other part of England (perhaps Yorkshire excepted). He had examined the strata at High Littleton in 1791, and resided in Bath in 1795, and again in 1799. One of his friends, the Rev. Joseph Townsend, rector of Pewsey, had in 1813 first published some of Smith's accounts of our Oolitic strata and their fossils. Townsend's work was entitled "The Character of Moses Established for veracity as an Historian, recording Events from the Creation to the Deluge." Reference was made to the Rev. J. J. Conybeare, who for eleven years was rector of Batheaston; and also to the fact that there was still living at Bath one of Sedgwick's earliest pupils, the Rev. Leonard Blomefield (formerly Jenyns), who had attended the Professor's lectures at Cambridge so long ago as 1819-20.* A fuller account was given of William Lonsdale, founder of the Bath Geological Museum, who, according to his own statement, became a geologist from hearing the conversation of two ladies in the library at Bath.† His memoir "On the Oolitic District of Bath," read before the Geological Society in 1829, was spoken of as an example of careful and accurate study; and one of his MS. geological maps (now in the possession of the Geological Society) was exhibited. Mr. Winwood also exhibited some of his MS. catalogues, which are marvels of neatness. Allusion was finally made to the enthusiastic labours of Charles Moore.‡

II. Dundry Hill.

Director: Edward Wilson.

On May 21st a party of members set out from the headquarters and took the 10.5 train for Bristol. They were met at Bristol station by the Director and Mr. W. H. Wickes, and having taken

* The Rev. L. Blomefield died in September, 1893, aged 93.
† See Memoir by W. S. Mitchell, *Proc. Bath Nat Hist. Club*, 1872.
‡ See Memoir by the Rev. H. H. Winwood, *Ibid.*, 1892.

their seats in a large brake, which was awaiting them, were driven rapidly through Bedminster and along the Bridgwater road, in the direction of the west end of Dundry Hill. The day was beautifully fine, and this with the charming prospect around, rendered the drive most enjoyable. A halt was first made at a quarry close to the edge of Bedminster Down. The attention of the members was here directed to a small section which showed some three feet of the regularly bedded limestones and shales of the Lower Lias (*Ammonites planorbis* beds), resting on about the same thickness of the rubbly limestones of the "White Lias," and beneath these a few feet of the greenish-grey laminated shales of the Upper Rhætic series, with an irregular bed of the well-known "Cotham marble" or "Landscape stone" at the top. The President considered that the arborescent markings of this bed were produced by changes amid the dark and light sediments during the solidification of the rock. In some places the bed is represented only by a banded limestone in a continuous layer. Where the arborescent markings occur the stone is in interrupted, more or less nodular, masses with a corrugated surface. Hence he thought these peculiar markings were due to the partial intermixing of the dark and light layers of mud during consolidation, when the soft sediment solidified in an irregular manner.*. The Director said he understood an unsuccessful attempt had been made to manufacture fullers' earth from the Upper Rhætic shales, and that this accounted for the exposure of the Cotham marble at this point. Proceeding about a mile farther along the Bedminster Down, the party made a second stoppage at a quarry close to the point where the footpath from Clifton to Dundry crosses the main road. Here a good section was exposed, showing about fourteen feet of the thin nodular limestones and dark blue shales of the *Ammonites angulatus* zone of the Lower Lias, covered by six or seven feet of the more regularly bedded limestones of the *A. Bucklandi* series. Amongst the fossils obtained from the spoil-banks of this quarry, and mostly if not entirely derived from the lower of the two series, were: *Am. angulatus*, *Nautilus* sp., *Gryphæa arcuata*, *Lima gigantea*, *L. pectinoides*, *Ostrea* sp., *Cardinia* sp. (casts), *Waldheimia perforata*, and *Rhynchonella calcicosta*.

Taking the road on the left just before reaching the first of the Barrow-Gurney reservoirs, the drive was continued up the hill until the gradient became too steep, when the brake was left by most of the members, and the rest of the climb made on foot. A cross road was presently entered, which cuts a little notch in the N.W. corner of the hill, and gives a small but interesting exposure of the lower beds of the Inferior Oolite (zone of *Am. concavus*), whilst at a little lower level on the same road, the local equivalents of the "Cephalopoda bed" of the Cotteswold Hills,

* See *Geol. Mag.*, 1892, p. 110.

with some of its characteristic Ammonites are disclosed in rubble in the bank. Although evidences of fossils in the Inferior Oolite were plentiful, the section was not in good working order, and little was obtained except the Brachiopods *Terebratula Eudesi*, and *T. Cortonensis*, and a few small Corals (*Montlivaltia*).

The members then walked to Dundry village, along the edge of the escarpment, from whence a magnificent prospect of the country to the north was obtained. The air being clear the chief physical features of the district—the range of the Cotteswold Hills from Kelston Hill on the south to Nibley Knoll and Stinchcombe on the north, the estuary of the Severn, and the elevated Palæozoic lands of South Wales beyond—were readily distinguishable, whilst nearer, the well-wooded hills of Carboniferous Limestone ranging from Clifton to Clevedon, the Gorge of the Avon, and the city of Bristol lying to the right, were interesting features in the landscape. Lunch having been taken at the village inn near the church, one of the adjacent freestone quarries in the Inferior Oolite (zone of *Am. Parkinsoni*) was visited. The Director showed a small series of the more typical Ammonites of the Inferior Oolite of Dundry, including specimens of the following Dundry fossils figured by Sowerby :—*Am. læviusculus*, *A. corrugatus*, *A. Sowerbyi*, *A. Braikenridgei (?)*, and *A. Brocchii.** Although the beds on the horizon of *Am. Parkinsoni*, which form the capping of the Dundry outlier, are fairly well exposed in the various quarries and at other points in the hill, the presence of the characteristic Ammonite of the zone was stated to be of extreme rarity. The complete sequence of the beds of the Inferior Oolite of Dundry has yet to be determined, and in particular the nature of the lowest beds of the series. It has sometimes been supposed that the "Cotteswold" or "Upper Lias Sands" of Gloucestershire, are represented in an attenuated form in Dundry Hill, but there is no visible evidence of their presence, and in some instances, at any rate, it appears that other beds have been mistaken for the "Sands."† There is, however, satisfactory evidence of the presence of all the important zones of the Inferior Oolite from that of *Am. opalinus* upwards, and also, as had been already observed, of the beds below on the border line of the Lias and the Oolites, known as the "Cephalopoda-bed" of the Cotteswolds. Whilst the close agreement of the Inferior Oolite of Dundry and Dorset, both in lithological and in palæontological characters and sequence—which has been indicated by the President of the Geological

* *E. Wilson*, "Fossil Types in the Bristol Museum," *Geol. Mag.*, 1890.

† *R. Etheridge*, On the Inferior Oolite of Dundry, in a paper by the late Dr. T. Wright, "On the Subdivisions of the Inferior Oolite of the South of England compared with the equivalent beds of that Formation on the Yorkshire coast." *Quart. Journ. Geol. Soc.*, vol. xvi. (1860), p. 20.

W. W. Stoddart, "Geology of the Bristol Coal Field, pt. 5, Jurassic Strata (Dundry Hill)." *Proc. Bristol Nat. Soc.* New Ser. vol. ii., pt. iii. (1878-79), p. 279.

Society and by Mr. S. S. Buckman, F.G.S.,* may be readily granted, and its divergence from the same series in the Cotteswold Hills, also freely admitted; yet every geologist will not perhaps be prepared to accept the precise form of the theory by which the latter authority attempted a few years ago to account for this divergence.

The party then walked across the fields to the far quarry on the Chew Stoke road. On the way fine views of the Mendip Hills were obtained, and at one point the President described the leading stratigraphical and topographical features of this remarkable range. The quarry now visited had not been worked very recently, and the section was somewhat concealed by fallen débris; so only a short stay was made, and beyond *Lima Etheridgei* and *Rhynchonella subtetrahedra* very little in the way of fossils was obtained. Rackledown quarry, another small exposure on the southern edge of the escarpment, about half-a-mile further east, was next visited, and being at the time in work, yielded the members more fossils. A good specimen of *Am. Sauzei* was found by Mr. Barham; and amongst other fossils, *Am. Murchisonæ*, *Ceromya Bajociana*, *Pholadomya Murchisonæ*, *Terebratula Eudesi*, and *T. Cortonensis* were obtained. The zones represented in each of these two quarries were indicated as those of *Am. Murchisonæ*, *A. concavus*, *A. Sauzei* or *A. Humphriesianus*, and *A. Parkinsoni*.

A pleasant walk across the fields brought the party to the quarry on the Chew Stoke road near the Butchers' Arms, on the north edge of the escarpment. Here the same sequence of beds was shown as at the last two quarries, with the exception that the working is not carried deep enough to expose the *Am. Murchisonæ* beds. Some blocks of the iron-shot oolite (*A. Sauzei* beds) had been got down by the quarrymen in anticipation of the visit of the Association; and these, with the heaps of road-metal in the quarry, supplied adequate material for the energies of the more vigorous members for an hour or so. Amongst the fossils obtained, Mr. Henderson found *Am. Brongniarti (?)*, and Mr. Duce *Opis similis*, whilst other members secured specimens of the following species: *Am. Brocchii* (senior and junior), *Pleurotomaria elongata*, *Trochus Zetes*, *Astarte excavata*, *A. elegans*, *Lima pectiniformis*, *Myacites Jurassi*, *Modiola* sp., and *Rhynchonella* (*Acanthothyris*) *paucispina*. The find of the day, however, was made by Mr. H. W. Monckton, who obtained a very fine fragment of a Crustacean, identified by Dr. H. Woodward as the carapace of *Eryma*, from a block of limestone apparently derived from one of the top beds.

* *W. H. Hudleston*, "Monograph of the British Jurassic Gasteropoda," *Pal. Soc.* part i. (1887), (Gasteropoda of the Inferior Oolite), p. 56.
S. S. Buckman, "The relations of Dundry with the Dorset-Somerset, and Cotteswold areas during part of the Jurassic period." *Proc. Cotteswold Nat. Field Club*, vol. ix, pt. iv. (1889) p. 374.

The following generalised section of the strata exposed in the two quarries on the Chew Stoke road has been published by Mr. S. S. Buckman*:

	ft.	in.
9 Limestone	6	0
8. Marl	0	9
7. Soft whitish stone	4	0
6. The Iron-Shot Bed. Hard brown iron-shot oolite, *Sonninia*, *Stephanoceras*, *Pleurotomaria elongata*, etc. [Zone of *Ammonites Sauzei.*]	1	0
5. Rubbly stone	0	4
4. Greyish limestone	0	7
3. White Bed below the Iron-shot. Greyish white stone, with numerous ferruginous grains. *Witchellia* frequent	0	6
2. Irregular marl	0	1
1. Nodular Bed. Marl, with irregularly-bedded limestone nodules, *Lioceras concavum*, *Hyperlioceras*. [Zone of *Ammonites concavus*]	0	6

After tea at the Carpenters' Arms, the members again took their seats in the brake, and the return journey was made in such good time that they were able to catch the 6.5 train for Bath.

III. BRADFORD-ON-AVON.

Directors: THE REV. H. H. WINWOOD AND W. H. WICKES.

ON Monday, May 22nd, there were several additions to the party, including Mr. W. H. Hudleston (President of the Geological Society) and Mrs Hudleston, Profs. J. F. Blake and Lloyd Morgan, with a Bristol contingent of geologists, increasing the numbers to about sixty. The 10.18 a.m. train was taken to Bradford, whither some of the more archæologically disposed of the party had started by an earlier train, the ostensible reason being an inspection of the celebrated Saxon Ecclesiola there, though by some it was shrewdly suspected that the early visit was made in order to secure the first pick of the Bradford Encrinites: it is almost needless to add that this suspicion was groundless. The real work of the day commenced under the directorship of the Rev. H. H. Winwood, who led the way to a section on the right bank of the canal, south of the town, and pointed out that the members were now at one of the classical sections described by Lonsdale, whose careful and painstaking labours in this district had been so well touched upon by their President on the previous Saturday evening. The section before them consisted of the upper beds of the Great or Bath Oolite upon which rested a bed of greyish clay, here about 10 feet thick. This deposit was considered by Lonsdale and the Geological Survey as belonging to the Forest Marble series and as being only a local member of that formation, but owing to the rich fossil-bed which occurs at its base, it had locally received the name of the Bradford Clay.

* "Monograph of the Inferior Oolite Ammonites of the British Islands," *Pal. Soc.*, pt. vi. (1892), pp. 292-3, footnote.

Though resting here on the Great Oolite, at Frome the latter formation was absent, and there the Forest Marble rested directly on the Fullers' Earth. In the opinion of the President the absence of the Great Oolite in this region south of Bradford-on-Avon, was due to the unconformable overlap of the Forest Marble series, for the horizon of the Bradford Clay had been traced in Dorsetshire, where it rested directly on the Fullers' Earth formation.* (See Fig. 1.)

Near the top of the Bradford Clay there might be seen two or three thin layers of gritty and shelly limestone very similar to the Forest Marble. Its chief celebrity is due to the beautiful specimens of the "Bradford Encrinite," *Apiocrinus rotundus* (or *Parkinsoni*), obtained here and more especially at Berfield by the late J. Chaning Pearce, who is reported to have purchased a field near Bradford for the purpose of securing the specimens in a perfect condition. Some of these he (the Director) had seen in a local museum in the city of Bath, and most beautiful they were. Through the kindness of Dr. J. C. Pearce, F.G.S., the fine collection made by his father was visited by the Geologists' Association at Brixton in 1885; but it has since been removed to Ramsgate.†

Locally known as "Peg tops," and "Coach wheels," from the resemblance of the head and stem to those articles, these "Pear Encrinites" would be found mainly at the base of the clay, and, owing to recent excavations for puddling-purposes, the roots of the Crinoids might be seen firmly attached to and forming a portion of the upper shelly layer of the Great Oolite. The other characteristic fossils were *Waldheimia digona*, *Terebratula coarctata*, *Rhynchonella varians*, *Ostrea Sowerbyi*, *Avicula costata*, etc. Sufficient time having been allowed for the fossil-collectors to add to their stores, Mr. Jones' quarry, called "Woodside," on the opposite side of the canal, was visited. Here the Bradford Clay is seen overlying the Great Oolite, but at a higher level than in the first section, where a local disturbance had thrown the beds down somewhat. The Director pointed out that the workable beds of fine Oolite or Freestone were some 10 or 15 feet thick here, that they were comparatively unfossiliferous and were thus more readily worked; the thick beds above and below them, called "rags," being coarser and more fossiliferous, were left to form the roof and floor of the quarries. Several of the members went underground to inspect the method of cutting out the freestone-beds, whilst others employed themselves in hunting for fossils in the Bradford Clay above. A thick bed of blue limestone lying on the top of the clay indicated the coming in of the Forest Marble which capped the rising ground above, and a section of which, worked for its fissile slabs, was seen on the right hand of the gate leading out into the Westwood Lane. A well at Leigh

* H. B. Woodward, *Geol. Mag.* 1888, p. 467.
† See *Proc. Geol. Assoc.*, vol. ix., p. 165.

Green, sunk through the Forest Marble and Bradford Clay probably into the Great Oolite, was said to be "main deep." This expression, as interpreted by a native female, meant about 150 feet, and this would give some idea of the probable thickness of the beds here.

Passing on to the Avoncliff (Ancliff) sections, still in the Great Oolite, a rotten band of limestone some 8 or 10 feet above the entrance to the main quarry was pointed out as the horizon whence Lonsdale and the Rev. George Cookson (who formerly resided at Westwood) had obtained many minute Gasteropods, some of which had been figured by Sowerby.* These included species of *Cylindrites* (*Actæon*), *Neridomus*, *Nerita*, *Pileolus*, and *Rissoina* (*Rissoa*). Polyzoa were also abundant. Mr. Hudleston remarked in reference to the Gasteropods, that it was to be regretted that such small forms had been taken as types, because some of them, at any rate, might be regarded as immature organisms.

Some of the ladies of the party were glad to rest for a while on a grassy mound and enjoy the lovely view of wooded slopes and winding river; whilst others descended to the river banks and ate their lunch under the welcome shelter of the "Cross Guns." After a short rest, the canal (here carried over the river by an aqueduct) was crossed, and on the north side, close to the bank, a veritable Troglodyte was seen. In a cave of the Inferior Oolite has lived for the past eight years one Charles Norris —(called locally Hookey Norris)—born as he said in Japan: short of stature, deformed in feet, with crooked hands and bushy beard obscuring a long and high coloured face, he looked scarcely human as the Director one day suddenly came across him squatting on a mound outside his cave and sunning himself. He seems to gain his living by making eel baskets, at which occupation he was engaged on this occasion. He pays a shilling a year for his shelter and was anxious to show the members his bedroom in a recess of the rock, and said that his chief visitors were the rats from the canal-banks in front.

Mr. Winwood now yielded up his leadership into the hands of Mr. Wickes, who led the members up a steep path to the high ground at Winsley. The Great Oolite Freestone is worked in the open as on Combe Down. The quarry showed a considerable amount of "head" or disintegrated oolite on top. After a short examination of this exposure the Director (Mr. Wickes) conducted the party by a pleasant and picturesque way to the old quarry of Murhill. Here a rich treat awaited the members in the shape of Corals, Polyzoa, and tiny univalve Mollusca like those of Ancliff. The quarry was worked some seventy years ago, but has long been abandoned. The fossil-beds lie above the freestone,

* The "Ancliff" fossils in the Bristol and other local museums are attributed to the researches of Lonsdale; Mr. Cookson's specimens are in the Sowerby collection at the British Museum.—W. H. WICKES.

and tumbled masses of these "rag-beds" strewed the floor of the quarry, which extended for several hundred yards along the scarp.

In some places the Coral and Polyzoan Beds were almost entirely composed of fossils. The Director pointed out the identity of the beds with those at "Ancliff," as illustrated by the following sections:

ANCLIFF.	ft.	in.	MURHILL.	ft.	in.
Rags and Rubbly Beds	5	0	Coral Band, with *Calamophyllia*, *Isastræa*, etc.	6	0
			Clay parting	0	4
Rags and Coarse Freestone: "Fossil Bed"	15	0	"Fossil Bed": with Polyzoa, *Entalophora* (*Spiropora*) *straminea*; Echinoderms, *Acrosalenia*; small Gasteropods, etc.	16	0
Marly clay	1	6	Clay, with Sponges, small Oysters, Crustaceans, etc.	1	6
Iron-bed and Rag	6	6	Rag	7	0
Freestone	5	0	Freestone	7	0

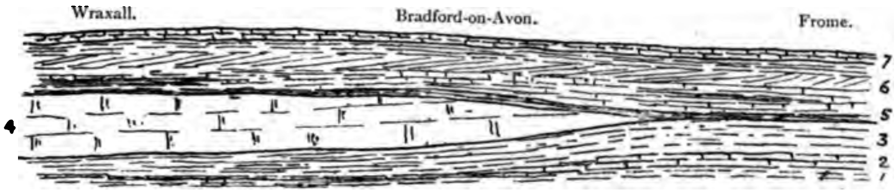
The members of the party then distributed themselves through the quarry, some examining the rocks *in situ*, whilst others searched among the fallen blocks on the floor of the pit; many fine specimens of Coral, especially *Calamophyllia* (*Eunomia*), were found here, and some good collections made. The Polyzoa Bed particularly attracted attention, and part of the "root" of a Bradford Encrinite was found in it. Several members searched for the small Gasteropods, which are found but sparingly in the Polyzoa Bed, and considering the time at their disposal, a good collection was made. Mr. Hudleston, to whom this little collection was handed, has kindly supplied the following list of species:—

Cerithium costigerum, *Piette*.
Exelissa formosa, *Lycett*.
Nerinæa, sp. (immature).
Pseudomelania or Fibula (immature).
Mathilda, sp. *cf.* "Chemnitzia" constricta, *Lyc.*
Rissoina acuta, *Sow.*
—— duplicata, *Sow.*
Rimula? clathrata, *Sow.*
Rissoa? lævis; *Sow.*
Turbo Burtonensis, *Lyc.*
Solarium turbiniforme, *Lyc.*

Mr. Hudleston remarks that owing to the state of preservation, one or two of the above determinations are open to doubt. Fragments of other species of Gasteropoda occur. The average length of the specimens is stated by him to be about 3mm., a rolled example of *Nerinæa* alone considerably exceeding this.

Attention having been called by the Director to the false-bedding and other features of the quarry, a rest was made at a spot overlooking the Avon Valley, one of the most beautiful views in the neighbourhood.

FIG. 1.—DIAGRAM-SECTION FROM NEAR BATH TO FROME.—*H. B. Woodward.*



7. Cornbrash.
6. Forest Marble.
5. Bradford Clay.
4. Great Oolite.
3. Upper Fullers' Earth Clay.
2. Fullers' Earth Rock.
1. Lower Fullers' Earth Clay.

FIG. 2.—DIAGRAM-SECTION TO SHOW THE RELATIONS OF THE OOLITE AND CRETACEOUS STRATA IN WILTSHIRE.

10. Chalk.
9. Upper Greensand.
8. Gault.
7. Lower Greensand.
6. Wealden Beds.
5. Purbeck Beds.
4. Portland Beds.
3. Kimeridge Clay.
2. Corallian Beds.
1. Oxford Clay.

H. B. Woodward, "Geology of England and Wales," Edit. 2.

The Members then descended the hill towards Limpley Stoke. On the way Mr. Winwood drew attention to the discovery of the Musk Ox (*Ovibos moschatus*) in the valley-gravel near Freshford; and some remarks on the formation of the valley were made by the President, and by Prof. Lloyd Morgan, and Prof. J. F. Blake. The Members took tea at the Hydropathic Establishment at Limpley Stoke, and then returned by train to Bath.

IV.—Westbury, Wiltshire.

Director: The President.

On Tuesday morning, May 23rd, the members had an opportunity, through the kindness of Mr. Winwood, of seeing the Bath Museum, and of inspecting the far-famed collection of fossils made by Charles Moore.*

Soon after ten o'clock the members started by train for Westbury. On arriving at the station they were met by Mr. J. R. Tennear (the Secretary of the Westbury Iron Company), who kindly guided the party over the iron-works. Very extensive excavations have been made to obtain the iron-ore, and the various sections showed in sequence the following divisions :—

		ft.	in.
Kimeridge Clay.	Blue Clay with *Ostrea deltoidea*, and ferruginous seams.		
Corallian Beds	4. Oolitic Ironstone, with seams of dark greenish and grey clay, and shelly layers composed of *Ostrea deltoidea*	10	0
	3. Grey and brown sands with seams of clay .	4	0
	2. Rubbly beds of marly oolite and pisolite, and marly clay.	12	0
	1. Fine wedge-bedded oolite	10	0

The Director pointed out that the Ironstone (No. 4) occurred in the same position as that at Abbotsbury in Dorsetshire; bed No. 3 might represent some of the Sandsfoot Beds of that region, while bed No. 2 perhaps included the horizon of the famous Coral-bed of Steeple Ashton. Bed No. 1 was the main mass of Coralline Oolite. These beds had been described by Messrs. Blake and Hudleston, but the lower strata were much more fully exposed than was the case at the time of their visit, and now Westbury afforded some of the finest sections of Corallian Beds in the country.

The false-bedded oolite at the base yielded *Echinobrissus scutatus*. The rubby beds (3) proved more fossiliferous, and a fine example of *Ammonites plicatilis* was obtained by Mr. Hudleston.† Traces of Corals were found by Mr. Wickes, and a layer

* See *Record of Excursions*, pp. 347-350.

† Mr. Hudleston remarks that the specimen closely resembles the figure in D'Orbigny's "Terrains jurassiques," pl. cxci, recorded in the text as *A. plicatilis*, Sow. It is probably the same as *A. varicostatus*, Buckland.

with *Pseudomelania* (*Chemnitzia*) *gigantea*, *Bourguetia* (*Phasianella*), *Natica*, etc., also occurred in the upper portion of these rubbly beds.

In the iron-ore a number of fossils were obtained, and among them some fine Ammonites. Two specimens, obtained by Mr. Leighton, were identified by Mr. Hudleston as *Ammonites Berryeri* and *A. decipiens*. *A. pseudocordatus*, *Cardium delibatum*, *Pholadomya hemicardia*, *Pecten distriatus*, etc., are among the species recorded by Messrs. Blake and Hudleston. Portions of lignite were observed.

There were two furnaces, but only one in blast. The ore is put into the furnaces with a certain amount of coke, and with some of the Coralline oolite for "flux." At two o'clock the members witnessed the interesting sight of the flow of the molten iron from the blast-furnace, the fiery stream running into moulds of sand, where it solidified in the form of "pig-iron." The slag was utilised for building-purposes and road-metal, and a paving material was made with the help of cement. A smart shower delayed the out-door proceedings for a short time, but the interval was occupied by an "extraordinary meeting" held in the waiting-room of the railway station, where Mr. Hudleston made some remarks as to the nature and possible origin of the iron-ore. He said that the deposit occupied a well defined position at the junction of the Corallian Beds with the Kimeridge Clay, and is very nearly on the same horizon as the ironstone of Abbotsbury about forty miles off, no similar beds being known to occur between the two points. The chief difference in the composition of these two ores lies in the more thorough oxidation of the Abbotsbury ore and its greater freedom from phosphates. He pointed out that the beds at Westbury shared a feature very common in Mesozoic ironstones, viz., an abundance of large Monomyaria, such as Oysters, Limas, Pectens, etc., in the associated beds, and that where this feature occurs there is often a large charge of phosphorus in the ore, due in part at least to the decomposition of the animal matter of these molluscs and associated organisms. Where the ore remains chiefly in the state of carbonate, as at Westbury and also in the Cleveland seams, the percentage of this impurity is usually rather considerable.

The question of "where did the iron come from?" was perhaps less easily answered with respect to these limited deposits at the top of the Corallian series than in many other ores of Jurassic age. He wished them to bear in mind that eighteen years had elapsed since he last visited this place, and now when they wanted to note the surroundings of the ore-beds, and more especially of the upper and overlying deposits, this unlucky shower had prevented them from doing so. In most cases a bedded ironstone, oolitic or otherwise, is the result of the ferrugination of calcareous beds, and such ferrugination had been effected either shortly after deposition or at a considerable interval. In almost all cases it is due to the leaching out of the iron in the overlying and surrounding beds through the action of organic acids arising from peaty and woody decomposition. Whatever the ultimate stage of oxidation may be, the charge of iron is in the first instance conveyed as carbonate, and the metal itself is derived from exhaustion of sands and clays which have been permeated by acidulous waters. Those members of the Association who went to Northampton a short time ago had an excellent opportunity for studying the result of operations of this nature, as almost every stage in the process of ferrugination of limestones through the leaching of overlying beds may there be traced.* He could not undertake to say that the iron ore of Westbury was due to precisely similar causes, though he recollected that the remains of much fossil wood clearly indicated the probability that organic acids had played an important part in concentrating the iron in the form in which it now occurs. This still remains for the most part in the form of carbonate, in consequence of the protection afforded by the overlying Kimeridge Clay, while the reddish-brown ironstone at the outcrop had subsequently been oxidized or "rusted." The lower Corallian beds showed little or no signs of ferruginous infiltrations, therefore he thought that this was an additional proof that we must look either to contemporaneous or overlying beds for the immediate source of the iron in the workable deposit.

The rain had now abated, and after visiting some other sections in the ironstone the members proceeded to the Eden Vale brickyard, where Gault clay is dug for the manufacture of red bricks, etc. According to Mr. Jukes-Browne the beds yield *Ammonites interruptus*, and contain small phosphatic septaria ; on the present occasion no fossils were obtained. The Gault here rests on the Kimeridge Clay, having overlapped or overstepped the Lower Greensand which is exposed at Seend and other places near Devizes. There were therefore two unconformable overlaps ; of Lower Greensand, and of Upper Cretaceous strata in this area. (See Fig. 2).

The proceedings terminated with a meat-tea at the Lopes Arms, Westbury.

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* See *Proc. Geol. Assoc.*, vol. iv, pp. 127-130 ; vol. xii, p. 186. See also W. H. Hudleston, "On the Geological History of Iron Ores," vol. xi, p. 104.

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EXCURSION TO DORKING.

SATURDAY, 3RD JUNE, 1893.

Directors: PROF. G. S. BOULGER, F.L.S., F.G.S., AND T. LEIGHTON, F.G.S.

(*Report by* THE DIRECTORS.)

THE object of this excursion was, as set forth in the Monthly Circular, to examine the district described by the Directors in a paper read before the Association on December 2nd, 1892. Full details of the controversy on the area in question having been published so recently (*ante*, page 4) no lengthened report is now necessary. The party arrived at Dorking at about half-past three, and proceeded at once to the southern end of the Horsham Road cutting (Section *A*); the other sections were afterwards visited in the order as lettered and described in the paper, up to and including Section *F*, at Buryhill. The key section at "The Rookery" was then visited, with the adjoining sections of Bargate and Hythe Beds in the cutting on the road to Wotton Hatch. The party then returned to Dorking to tea.

At Section *B* the extremely dry weather had made it clear that the mixed character of the beds there shown was due to the slipping down of Folkestone Beds from above over the "dirty" sands, presumed to be of Sandgate age, below. The possibility of this is suggested in the paper. The section of the "clayey" sands on the western side of the road was carefully examined, and in it nodular concretions were found containing casts of fossils.*

* A chemical examination of these nodules has kindly been made by Mr. W. Tate, A.R.C.S., who finds them to consist mainly of insoluble material (sand): the portion soluble in acid gives good reactions for Iron and Phosphoric Acid, while Calcium Carbonate is present in very small proportion.

A cast of a chamber of an Ammonite was recognised: one of Neocomian type, but not *A. Deshayesii*, the only Sandgate form recorded inthe Weald Memoir.*

At Section *E* a surprise awaited the party. Whilst it was seen that the Directors were correct in describing the section as "undoubted Hythe Beds," so far as their material was concerned, it was equally clear, and at once admitted, that the beds were not in place. A better exposure now showed that the section was in a gravel in every way similar to that described by the Directors lying on the Gault near Bushy Plat, on the other side of the Pipp Brook (*ante*, p. 9). Careful comparison of the 6-inch Ordnance Map with the Drift Edition of the Geological Map further proved that this patch of gravel is shown on the latter, although the topographical details are somewhat misleading. When these sandstone beds of the Hythe Series lie immediately below the soil, they become rubbly through surface weathering, and in a shallow section may easily be mistaken for drift. To appreciate this the "gravel pits" on the top of Leith Hill should be examined, where there is no suspicion of drift, and yet the beds immediately below the surface are regularly worked for "gravel." This correction makes no difference to the reading of the geology of the area adopted by the Directors, but actually removes a difficulty which could only be accounted for by presuming that the fall of the surface towards the town of Dorking was less than the dip. The supposed inlier of Hythe Beds, however, does not exist.

At Section *F* the cutting of a shallow drain showed the silver sands of the Folkestone Beds even more conclusively than usual, and, though unfortunately the Geological Survey was not represented in the party, the most sceptical seemed convinced of the correctness of the new reading.

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1893. BOULGER, G. S., and LEIGHTON, T.—"On the Lower Greensand . . . between Wotton and Dorking." *Proc. Geol. Assoc.*, vol. xiii, part 1, p. 4.

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* [Since the date of this Excursion Mr. F. Chapman, F.R.M.S., has found in these clay-bands an interesting series of minute Foraminifera—all Arenaceous.—ED.]

EXCURSION TO HYTHE, SANDGATE, AND FOLKESTONE.

SATURDAY, 10TH JUNE, 1893.

Directors: F. G. HILTON PRICE, F.S.A., F.G.S., AND THOMAS LEIGHTON, F.G.S.

PART I. HYTHE TO FOLKESTONE.

(*Report by* THOMAS LEIGHTON.)

A PARTY numbering upwards of 40, and including Mr. John Griffiths, the veteran fossil collector of Folkestone, assembled at Sandling Junction Station at a quarter to eleven. A move was at once made by the high road to the railway cutting near Saltwood, on the branch line to Sandgate. It should be remembered that the Saltwood Tunnel, described in Mr. Topley's "Memoir of the Weald" (p. 128), is on the main line to Folkestone, a little to the north of the tunnel adjoining the section about to be described. The beds described in the first Saltwood Tunnel, however, appear to be the same as those shown in the cutting adjoining the second tunnel.

From the level crossing near Saltwood Church the party proceeded up the line to the tunnel (No. 2), which is driven through the Folkestone Sands, just beyond their junction with the Sandgate Beds, which junction it was pointed out might be taken at the line of vegetation rising through the bank. Mr. Leighton here explained that he had only undertaken the direction of this portion of the excursion as the monthly circular was going to press, in consequence of the unfortunate illnessof Mr. Hilton Price; the latter gentleman would meet the party at Folkestone in the afternoon, but he was not at present sufficiently recovered to undertake the whole of the day's work. Mr. Leighton said under these circumstances, since he was known to be somewhat unorthodox on the subject of the Lower Greensands, it would be his duty simply to describe the beds as they were interpreted and mapped by the Geological Survey, but he would not hold himself responsible for the correctness of those views, and when he differed from them he hoped he might be allowed to point out his reasons for such difference.

"The buff sands," Mr. Leighton proceeded to say, "through which the tunnel is driven, and which are seen at the north-west end of the cutting, are the Folkestone Sands, in the condition described on page 139 of Mr. Topley's Memoir (and quoted by Professor Boulger and myself on page 12 of the 'Proceedings,' vol. xiii). You will notice that the section consists of buff sands only, such as you are accustomed to recognise as Folkestone Sands throughout Surrey, the hard beds of stone, chert, etc., which you will see presently between Sandgate and Folkestone, have disappeared here. I will now call your attention to the dip. In his communication to *Nature* of March 16th last, our late President, Prof. J. F. Blake, describes the Sandgate Beds as dipping east at a moderate angle, but you will see that that is certainly not the dip here, for, since this cutting runs almost exactly north-west south-east, it is obvious that a true easterly dip should show beds falling slightly down the line, whereas you see them falling somewhat sharply up the line. The dip as seen here agrees with that given by the Survey, which is a little east of north. I believe this to be the true dip throughout this area, although of course there may be local dips in many places. Now as to the Sandgate Beds themselves, the uppermost member of which is before you, you see a dark grey clayey sand, it would appear more clayey but for the continued dry weather of the last three months; still, although not by any means strictly impervious to water, the line of springs occurs at the junction of this bed and the Folkestone Beds above. There are less pervious beds below and this bed itself would soon become water-logged As we proceed down the line, you will first come to dark green stratified beds, clayey sands in various degrees of admixture, but always more sandy than clayey. Below these you will find more homogeneous beds, almost black in colour, concerning which there is evidently some confusion, but confusion for which I fear this Association is mainly responsible.

I must now be considered as speaking for myself alone, as what I am about to tell you is not in accord with the published description of previous observers. Before I touch upon the point in question, however, I wish to say that in my opinion we are still far too ignorant of our Lower Greensand area as a whole to be able to say for certain that any one bed is anything more than of Neocomian age. Mr. C. J. A. Meÿer has done excellent work in the Godalming district, but until the whole area has been examined with equal care I do not see how the various beds can properly be brought into line. We know far too little of the fossil contents of these beds. I may instance that although Mr. Hilton Price calls the bottom bed of the Sandgate the zone of *Rhynchonella sulcata*, in the table of fossils published in the Weald Memoir, that species is not recorded from the Sandgate Beds at all, but only as occurring upwards from the Folkestone Junction Bed (zone of *Am. mammilaris* ?). I must presume that the junction bed referred to is the zone of *Am. mammilaris*, although that species is not recorded in the same table from the Junction Bed but from the Folkestone Beds themselves, but that may be simply a printer's error. I mention these matters only to show that one has excuses for being a little unorthodox. Now as to the bottom bed of the Sandgate, I have little fault to find with the Survey Memoir, none with the facts as there stated, but I believe the correlation (page 128) of the 'clay, dark green, tough and adhesive, almost black when first brought to the surface, and containing very little sand,' found by Mr. Simms in the Saltwood Tunnel No. 1, with the upper part of the Sandgates (the green clayey sands) of Mill Point, to be an error. No doubt that was the best correlation that could be made at the time, when evidently there was not much evidence. I have myself seen the black clays below the green clayey sands at Mill Point, but of course exposures there vary according to the state of the slips. Professor Blake describes both beds as exposed there this spring in his paper in *Nature (op. cit.)*; I saw the same beds with him the Saturday after the landslip, both here and on the shore at Sandgate, and you will see both these exposures to-day. Mr. Simms's clay, I should say without doubt, is at the bottom of the Sandgate Beds.

"Now as to the confusion concerning this bed for which we are as an Association more or less responsible. In vol. iv of our 'Proceedings,' on page 136, we published a section by Mr. Hilton Price, which shows the bottom Sandgate Bed as a 'clayey bed': this is correct, but in the description accompanying the section it is described as 'black sands.' Now, was this through a printer's error? I am, of course, quite unable to say. The matter did not, however, end here. In 1883 a new section was drawn for us by Mr. Topley, details of the Sandgate Beds taken from the *description* accompanying Mr. Price's section, and thus the wrong description of the bottom bed of the Sandgate was perpetuated, and that section we have reprinted recently.* Now since we are obviously more or less to blame for all this, I think the best thing we can do is to go to the section and decide how we are to describe this bed in future."

The party walked down the line to the section, which was unfortunately very dirty from the long drought. Mr. Leighton produced a sample of the bottom bed for an opinion, when Mr. Holmes stated that he would prefer to call it a loam, although no doubt it would be impervious to water. Mr. Leighton said it was a great pity the weather had been so dry, but he would accept Mr. Holmes's definition with the qualification that it was a "stiff" loam.

No report of this excursion would be complete without reference to a discussion which was initiated here by Mr. C. J. A. Meÿer, and well maintained by him and some others at various points during the day. On behalf of the opposition, Mr. Meÿer asked, without committing himself to the opinion that it was so, why the clayey beds in the railway cutting should not be the

* This vol., p. 42.

Atherfield Clay, given as about fifty feet thick here, and the buff sands overlying them, the lower beds of the Hythe Series as seen in Surrey? The beds hereabouts were much faulted and broken up by the collapse of clays on the shore, and he particularly wished to know on what grounds the buff sands, differing so materially from those seen in the coast section from Sandgate to Folkestone, were classed with them as of Folkestone age? Mr. Leighton said that the explanation he had given was strictly in accord with the Survey mapping, with which he fully agreed so far as our present knowledge extended. He would prefer to have some evidence of faults before dealing with them, and further he thought that as the party proceeded along the road to Hythe it would become clear enough that the clayey beds of the railway cutting were regularly superimposed on the Kentish Rag Beds of the Hythe Series. As to the buff sands at the base of the Hythe Series in Surrey, he had never seen any sign of them in this district, and a very considerable lithological change from east to west being admitted on all hands, he did not see why their absence here should be noteworthy. The junction of the Kentish Rag Beds and the Atherfield Clay had been seen at Hythe and there was no buff sand between.

Leaving the railway at Saltwood Castle the party took the high-road to Hythe; when near the cross-road close to the edge of the Sandgate outcrop, Mr. Deedes, of Hillhurst, near Hythe, informed the party that the land hereabouts was "very heavy, difficult to work." Mr. Leighton at once pointed out that this was the result of, and evidence of, the clayey nature of the bottom bed of the Sandgate Series. At Hythe the old sea-cliffs, now inland, were examined and explained, the party then proceeded to the eastern quarry of the Kentish Rag, the beds of which were briefly described. The best fossils are found in the other quarry, to the west of the road by which the party arrived; that quarry was not in the programme on this occasion however, from want of time.

Proceeding towards the railway station the clay-pit close at hand was visited. The blue clay now chiefly worked is evidently the Weald Clay, as shown by the presence of Cyprids, but the bluish-grey sandy clay at the top of the section may represent some of the squeezed-up Atherfield Clay. A short visit was paid to the old pit immediately above, but marsh plants were the only evidence, that could now be found, of the Atherfield section which was shown here on a previous occasion. The party took train at 1.21 p.m. from Hythe to Sandgate and upon arrival proceeded at once to the foreshore, where the recent removal of shingle has left the beds well exposed in places.

Below the military hospital and but a short way from where the sea-wall shows the commencement of the landslip, Mr. Meÿer found a shale with *Paludina*, evidence of the presence of the

Weald Clay. This would appear to come in at about its normal horizon, but the find is an interesting one which the natural craving for lunch alone hindered from complete investigation at the time. Judged roughly on the spot the distance from the outcrop of the top bed of the Hythe might be forty paces, which would bring the position well within the Weald Clay. The matter is, however, well worthy of careful measurement since it is just here that Professor Blake draws his westernmost fault. The outcrop of the Hythe Beds was carefully examined, with the clays and green clayey-sands of the Sandgate Beds squeezed up above them by the landslip, still well exposed on the shore.

Mr. Leighton then drew attention to the ledge of Hythe limestone further to the east, dipping in-shore at a high angle, which he agreed with Professor Blake must necessarily show the existence of a fault, or of a disturbance such as Mr. Topley allowed of so considerable a nature that it amounted to a fault. It would appear however that Professor Blake has drawn his fault (*Nature*, *op. cit.*) too far to the east, since evidence of the highly inclined ledge was found high up on the shore in a position which accords well with the old quarry mentioned by Mr. Topley in his paper. There is no other evidence of fractures or of slipped ground at this part of the shore and since the main outcrop of the Hythe Beds, showing a considerable width of limestone bands regularly ranged in line, must almost necessarily show the true dip, and the fault throws the Hythe Beds up into the cliff, it is not easy to accept Mr. Topley's explanation of the cause of the high dip noted by Professor Blake. Mr. Topley's explanation of the high dip, however, might apply to masses torn off to the east of the fault, nevertheless there is good evidence that a fault must exist, since there appears to be a complete succession from the Weald Clay to the Sandgates on the shore to the west. Further, Mr. Topley has seen the Hythe Beds in the cliff near Wellington Terrace, at which point they cannot be brought into line with the outcrop on the shore since they are but sixty feet in thickness.

Mr. Leighton stated that he did not exactly understand Mr. Topley's comparison of the landslip in this district with those to the east and west, from which almost all Mr. Topley's illustrations were drawn. He thought that different causes entirely must be found to account for landslips here, to those seen in operation at the Warren beyond Folkestone, or at Hythe. At both those places solid beds (Chalk at the Warren, Hythe Beds at Hythe) slipped over and plunged through, slippery clays, but at Sandgate the loose Folkestone and Sandgate Beds rested on the Hythe Limestone, the foundations of which appeared to be protected. Mr. Leighton was not prepared to admit that there was an undercliff formed by landslips between Sandgate and Folkestone. He looked upon the strip of ground there beneath the cliff as talus mainly. Of course a discussion might be raised here as to what constituted a land-slip, but east of the point where the lower Folkestone road diverged, atmospheric weathering appeared to be the chief destroying agent, and falls of rock and sand from that cause were locally, although not correctly, termed landslips.

After luncheon at the Royal Kent Hotel Mr. Leighton briefly described Mr. Topley's views of the nature of the Sandgate Landslip, which will be found on page 40 of this volume. Mr. Leighton added that considering that there was considerable difference between Mr. Topley and himself as to the details of the local geology, which he had endeavoured to explain during the morning, it was somewhat surprising that little if any difference existed as to the cause of the landslip. Indeed, he did not see quite how Mr. Topley accounted for the slip at all if the Sandgates were "not completely retentive." Mr. Leighton thought that the broken rocks of the undercliff had slipped forward on the Sandgate Clay, but since we had had many wet periods in the past without a landslip he was inclined to think that the removal of shingle from the foreshore, which was far more extensive than was generally supposed, must be said to be the chief cause of the slip. It was the only visible cause, since, although he would like to have some details of the slip of 1827, he looked upon the Sandgate undercliff as practically at an angle of rest, under ordinary conditions. The undercliff was well covered with soil everywhere and there were no signs of slips over the broken ground before the present year. Water falling on the surface of the undercliff would not do any damage, but it was worthy of remark that after the slips had occurred several springs broke out at unusual places and were yet running in spite of the long drought. This looked as if from some (unascertained) cause the water-line in the Folkestone Beds had risen, so that although the dip was inshore, water had poured over into the broken rocks, which had thus become too heavy, with the withdrawal of the support of the shingle, to maintain their previous angle of repose. Of course this was more or less problematical, still it would be seen that in the Encombe Grounds and elsewhere the slip had exposed the junction of the Folkestone and Sandgate Beds in the small sections, and why should water now come from this junction at spots which were not so affected previously by wet seasons? Mr. Leighton thought, therefore, that water must be a cause of the landslip, although at present it was impossible to say precisely how it had been brought into operation.

The determination of the Sandgate Local Board to drain the line of junction of the Folkestone and Sandgate Beds would render matters secure in future. Mr. Leighton said he was glad to read in Mr. Topley's recently published paper that this was to be done, as he was interested in the welfare of Sandgate and had little faith in the deep drains at right angles to the cliff which he had, perhaps erroneously, understood to be the plan proposed at the time the paper was read. After examining the chief places of interest on the slipped area, the party took the lower road to Folkestone in the high section above which the peculiar local characters of the Folkestone Beds were noticed, as mentioned above. At five o'clock Folkestone harbour was reached; here Mr. Hilton Price joined the party and at once undertook the direction.

PART II. FOLKESTONE AND EASTWEAR BAY.

(*Report by* F. G. HILTON PRICE.)

The party first proceeded to the end of the pier in order to get a good view of the cliff sections of the Upper Neocomian Beds to the east. Mr. Price then said:—

"This section consists of the Sandgate Beds, the Folkestone Beds, with the Gault capping them. The Sandgate Beds consist of four divisions, and are supposed to attain a thickness of about eighty feet, but as they are below tide mark very little beyond the upper part of bed IV. is seen. The base bed No. I. is composed of black clayey sands, and is very fossiliferous, containing *Rhynchonella sulcata*, *Astarte*, sp., *Crassatella Cornueliana*, *Cucullæa glabra*, *Cytherea*, *Corbula*, *Exogyra sinuata*, *Gervillia anceps*, *Myacites plicata*, and others. This bed can only be got at during the spring tides, and the fossils are very difficult to preserve.

Bed II. consists of dark green sands, passing up into yellowish green sands containing a few fossils.

Bed III., black clayey sand.

Bed IV., yellowish-green sands, which are succeeded by brownish clayey sands.

"The Folkestone Beds, which are about seventy feet in thickness, rest conformably upon them. Bed I. of this series consists of a brown ferruginous sandstone about one foot in thickness, containing phosphatic nodules, many much rolled, in which casts of fossils occur, such as: *Corbula*, *Cucullæa*, *Lima*, *Lucina*, *Trigonia*, *Avellana*, *Janira Morrisii*, and two Ammonites.

"At Baker's Gap, which is half-way between the harbour and Copt Point, a slight anticlinal can be seen in the cliff, and false beddings may also be noticed.

"Bed II. is about two feet in thickness and consists of dark greenish clayey sandstone, reminding us of the hassocky Hythe Beds, which have been seen this morning; it is fossiliferous, containing amongst others: *Serpula*, *Rhynchonella*, *Waldheimia pseudojurensis*, *Avicula pectinata*, *Ostrea frons*, *Pecten orbicularis*, and *Janira Morrisii*.

"Bed III. is about sixty feet thick, and consists of seams of coarse calcareous sandstone, varying from two feet to a few inches, all of which are interstratified with layers of loose yellowish sands. It is from this bed that the Folkestone stone is extracted, largely used for building purposes. You will observe large white tabular masses of branching sponge upon the rocks and boulders. Twenty feet up the sand takes a black clayey character, but this is not constant; *Pecten orbicularis* has been found in it About ten feet from the top a seam of chert occurs. You will observe upon the rocks many large specimens of *Exogyra sinuata*, which come from this bed, and many other fossils have been found.

"Bed IV., which is styled the zone of *Ammonites mammilaris*, consists of an irregular seam of large rolled nodular masses ot grits, composed of coarse grains of quartz, glauconite, jasper, and phosphatic nodules. These nodules require a very heavy hammer to break them; when broken up they will be found to contain rolled casts of a great many fossils and dark pipings of Gault, they have the appearance of having rolled about on a shore for a long period of time and when in a soft state they accumulated the debris lying on the shore.

"This seam is succeeded by about four feet of loose yellowish sands and is capped by a line of pyrites nodules which forms the base of the Gault.

"All these before cited beds dip N.N.E., and finally disappear below the beach a little eastward of Copt Point."

The party then walked round the harbour and Mr. Price pointed out the site of the "Elephant Bed" at the Battery on the West Cliff, just above the road opposite to the Pavilion Hotel. Some years ago a large quantity of bones of large mammals was found here: many of them are deposited in the Folkestone Museum.

Having descended to the beach to the east of the harbour, a stiff walk brought the party to Copt Point, where small sections showing the various fossil horizons of the Gault had been prepared by Mr. Griffiths. Mr. Price then resumed his discourse as follows:—

"Copt Point, composed of Gault, is gradually growing smaller and smaller, probably nearly a quarter of a mile of it has been denuded since the beginning of this century, but by far the greatest havoc has been caused to it and the whole of Eastwear Bay since the South Eastern Railway built out their extension of the pier.

"The Gault is here at Copt Point about 100 feet thick, the whole of the lower Gault and part of the upper is here *in situ*; to get a section of the remainder of the Upper Gault you will have to walk about a mile further east.

"Round about Copt Point on the shore at low water a large quantity of fossil wood, specimens of *Ammonites interruptus*, and other ammonites and fossils can be readily picked up. After passing Copt Point no more cliff is seen, as the whole area between the chalk hills on the north and the beach consists of the results of landslips, confusedly mixed with the chalk detritus thrown out when the tunnels and railway were constructed. Landslips are of frequent occurrence here in the wet seasons and many serious ones have been observed.

"Before proceeding further I may tell you that the Gault is divided into two large divisions and again subdivided into eleven zones or beds, to all of which numbers and names have been given, indicative of the colours of the clays or of their fossil contents.

"The lowest bed, No. I., is the zone of *Ammonites interruptus*. The clays of the Lower Gault, with the exception of the Crab Bed, No. III., is of a dark colour and contain a larger proportion of oxides of iron and pyrites than the clays of the Upper Gault, which contain far more lime and less iron. The fossils of the Lower Gault are frequently highly pyritised and of a brilliant colour, whereas those of the Upper Beds are frequently enveloped in phosphate of lime. A large number of Lower Gault fossils became extinct in bed VIII., the nodule or junction bed. Taking the list of the fauna from my paper on the Gault as 292 species, as many as 124 species appear to be extinct in this junction bed and 46 forms are continued into the Upper Gault; it also contains 20 species peculiar to it, and 57 new species occur in the beds of the Upper Gault. You will observe as you walk along the shore tabular masses of a light fawn-coloured iron stone, perforated throughout with the borings of some mollusc; this comes from Bed III.

"Selinite occurs in large pieces in Bed II., and in no other part of the Gault.

"Before leaving the Lower Gault it will be well to note that most of the Siphonostomata become extinct in the passage bed No. VIII.; with the exception of a few species of *Aporrhais*, the fossils of the Upper Gault are mostly Holostomata.

"As we come upon bed IX. we find the silvery casts of *Inoceramus sulcatus* in great abundance; a hybrid form is also found here, called *Inoceramus subsulcatus* from which circumstance the bed is aptly named by Griffith the 'half-and-half' bed. The crushed band of *Inoceramus sulcatus* marks the division between this zone and Bed X. The Gault now becomes more homogeneous and hard and has a pale cold grey colour and is poor in organic remains. *Kingena lima* is found here, which gives the name to the bed.

"The next and uppermost bed of the Gault consists of hard cold grey marls, and is upwards of fifty-six feet in thickness, in fact thicker than the lower ten beds put together. The best place to see this bed *in situ* is that part of Eastwear Bay known as the Pelter (after the name of a brig wrecked here). About thirty-five feet up in this bed there is a band of dark greensand three feet three inches in thickness, this latter was measured by cutting a section east of Copt Point and south of Martello Tower No. 3. Seventeen feet above this is the so-called Upper Greensand *in situ*. The Gault above this seam of Greensand, called the Middle Greensand by Griffith, is of the same consistency as that of the same bed below. Casts of very large Ammonites occur in this zone.

"The dark greenish sand, calcareous and clayey, commonly called Upper Greensand, reposes more or less conformably upon the Gault, into which short pipings extend for about three or four inches. It is simply the sandy base of the Chalk Marl, into which it gradually passes upwards. It is about fifteen feet in thickness, and is followed by my bed II. of the Chalk Marl, about ten feet in thickness, very hard and coarse in texture and very fossiliferous.* Then comes on the soft grey Chalk and the Lower Chalk, but the Chalk is out of our province to-day."

The examination of Eastwear Bay was somewhat interfered with by the target practice of a battery of artillery, nevertheless a small party accompanied the Director through the Warren to see the effects of the various and frequent landslips upon this area, upon which an interesting paper has recently been read before the Association by Mr. Topley. Within the memory of man the land extended fully a quarter of a mile further seawards than at present. After tea at the Warren Inn the party returned to town.

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New Ordnance Survey Map, Sheet 305.

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See also the References given on p. 47.

* See "The Beds between the Gault and Upper Chalk near Folkestone," *Quart. Journ. Geol. Soc.*, vol. xxxiii, p. (1877.)

EXCURSION ALONG THE NEW RAILWAY FROM BLACKHEATH TO BEXLEY HEATH.

SATURDAY, 17TH JUNE, 1893.

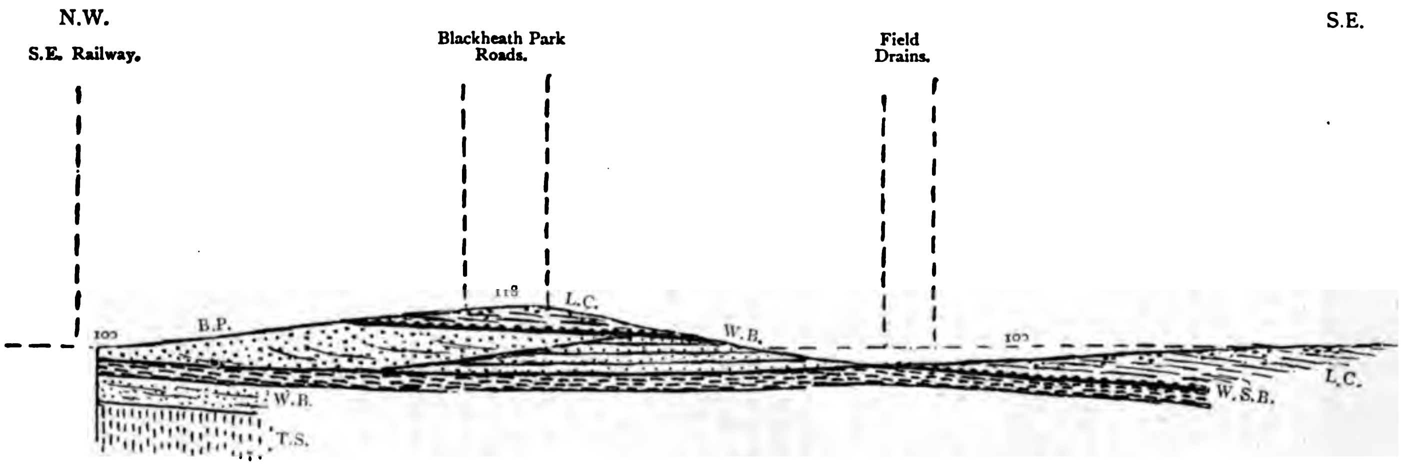
Director: T. V. HOLMES, F.G.S.

(*Report by* THE DIRECTOR.)

PERMISSION for our visit having been kindly given by Mr. Rigby, the contractor, the party assembled at Blackheath and proceeded to the junction of the old and new lines, about a quarter of a mile east of Blackheath Station. There, a few feet south of the old line, a deep timbered excavation was seen. At one end of it the surface was seen to consist of Blackheath Pebble Beds. Beneath these, at a depth of 5 or 6 feet, were the shell-beds of the Woolwich Series, their thickness being about 8 feet. Below the shell-beds appeared yellowish and greenish sands containing pebbles towards their base, while at the bottom of the pit, at a depth of about 28 feet, the excavators had touched the light buff Thanet Sand.

Leaving this spot, the party crossed the road which traverses Blackheath Park from east to west. The railway is to run in a tunnel beneath this and another road, and there are at present (June, 1893) some deep open excavations on its southern side. The first visited had its more northerly end about 20 yards south of the road. At the bottom was the Woolwich Shell-bed, its top being about 27 feet below the surface. Above it were four or five feet of sand with partings, then Blackheath Pebble Beds, sandy towards their top and containing many shells towards their base. In some places they had become a hard, shelly conglomerate. Above, forming the surface, was London Clay, having at its base a pebble-band of from about 8 to 15 inches, and attaining a maximum thickness of 6 or 7 feet. Here as elsewhere along our route, we saw irregular deposits of pebbles above the London Clay, close to the surface. A few yards further on, towards the southern face of the bank now being tunnelled, London Clay with its basement pebble-band was still seen to form the surface to a depth of two or three feet, but the Blackheath Pebble Beds had disappeared, and the basement bed of the London Clay rested upon 13 or 14 feet of laminated sands with clayey partings, the Woolwich Shell-bed appearing at the bottom of the cutting beneath them. The Director pointed out the close resemblance between this last section and that at Loam Pit Hill, Lewisham, where the Blackheath Pebble Beds were entirely absent. Here,

SECTION I.—SECTION FROM JUNCTION WITH S.E.R. EAST OF BLACKHEATH STATION TO A POINT S.W. OF LOWER KIDBROOKE FARM.—*T. V. Holmes.*



Figures 100, 118 show the height of the surface. L.C. London Clay. B.P. Blackheath Pebble Beds. W.B. Woolwich Beds. W.S.B. Woolwich Shell Bed. T.S. Thanet Sand.

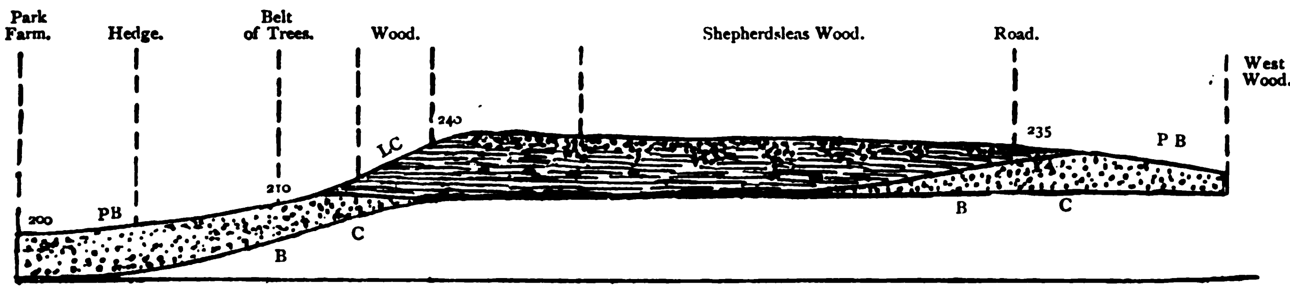
Scales:—Horizontal, 6 inches = ½ a mile; Vertical, ½ of an inch = 20 feet.

however (he added), a few yards to the north, the Blackheath Pebble Beds were visible, though only to a thickness of 14 or 15 feet, or less than half that attained at Blackheath, about half-a-mile away to the north-west. But the most interesting feature of this Blackheath Park section was the way in which the London Clay rested unconformably, not merely on an eroded surface of the Blackheath Pebble Beds, but also on one of the Woolwich Beds. Mr. Whitaker had noted* that "in the western part of the London Basin this bed [London Clay] often rests on an uneven surface of the Reading Series," but had not mentioned any case in an eastern district. Here, however, in the hollow at the southern base of the gentle eminence on which they were standing, where the field drains approached the line, he (the Director) had seen in a drain the top of the Woolwich Shell-bed covered by a pebble band, which was evidently that at the base of the London Clay, as from that point eastward the whole of the cutting to its end south of Lower Kidbrooke Farm was in London Clay, irregular deposits of pebbles appearing on the surface. (Section 1.)

Between Lower Kidbrooke Farm and the Woolwich and Eltham road south of Well Hall, the railway will be on an embankment. East of the road just named Blackheath Pebble Beds appear, at first in a bank south of the railway where they contain many oyster and other shells, and a few yards further on, in a cutting deepening eastward. Park Farm (Section 2) is a few yards north of the north-westerly corner of Eltham Park, and the high ground where the London Clay comes on is equally near to its north-eastern limit. Between these two spots the proportion of sand to pebbles was seen to increase very much eastward. When, however, we had passed through the central portion of the long cutting, in which the sides were of the overlying London Clay, and had reached the eastern border of Shepherdsleas Wood, we found that the pebbles decidedly predominated over the sand. Halting for a few moments at a spot near the north-western border of Eltham Park the Director remarked that a few yards southward the Blackheath Pebble Beds were known to have an average thickness of about 40 feet. In the well for the supply of the house at Eltham Park they were 44 feet, and in the shaft of the remarkable artificial cavern or denehole, discovered in Eltham Park in 1878, they measured about 37 feet 9 inches. Excavations were made in Eltham Park in 1878, by order of Mr. Thomas Jackson, the proprietor, in order to remedy a defect in the water supply. A leak was found, and the workmen were directed to trace the course of the water that had escaped. It was found to run into a disused brick drain, which ended at the top of a deep covered-in shaft. The top of the Chalk was 116 feet below the surface, and the total depth of the shaft 140 feet. It ended in a large chamber about fifty feet long by thirty

* "Geology of London," vol i, p. 238.

SECTION 2.—SECTION FROM THE N.W. CORNER OF ELTHAM PARK TO THE BORDER OF "WEST WOOD," ON THE BLACKHEATH AND BEXLEY HEATH RAILWAY (May, 1893).—*T. V. Holmes.*



The figures 200, etc., show the height of the surface. The line B.C. marks the bottom of cutting.
L.C. London Clay. P.B. Blackheath Pebble Beds.

Scales:—Horizontal, 6 inches = 1 mile; Vertical, 20 feet = ¼ of an inch.

broad, and nine feet high, the roof being supported by three pillars of Chalk in the centre line of the chamber. This shaft was north of the house and south-east of the farm buildings, and on the eastern side of the road connecting them. Those wishing for further details he referred to a paper about it by Mr. W. M. Flinders Petrie in the *Archæological Journal* for 1878.

In the middle of the arable land, still known as "West Wood," the cutting ends and is replaced by an embankment. After tea at the Nag's Head Inn, Welling, the party pursued its way eastward. On the eastern side of the road ranging northward from Crooklog a small outlier of London Clay is shown on the Geological Survey map (1 S.W.). The railway crosses this patch nearly at its centre. A few shallow pits along the course of the line were seen here and there, in and on both sides of this outlier. One within the outlier showed about 6 feet of London Clay, a more satisfactory section, the Director remarked, than any he had hitherto seen there. He added that his experience along that line generally had been that as the sections became clearer and better developed, so Mr. Whitaker's extreme care and accuracy had become more and more evident. Many months ago, when the Blackheath Park and Eltham Sections were very inferior in depth and clearness to what they had since become, he had thought that the new line would cause very considerable changes in the Geological Survey map. Had his early notions turned out to be correct, no discredit could rightly have attached to Mr. Whitaker on that account, the nature of the beds and the amount of evidence at his disposal being remembered. But the better the sections the more accurate had the Survey mapping shown itself to be.

Leaving the London Clay outlier, the party passed over ground giving evidence of pebble-beds at the surface, and came to a cutting gradually deepening eastward, and reaching a maximum of about 35 feet between Long Lane and Threecorner Wood. East of Conduit Wood the line is on an embankment. Towards the western end of the cutting, south of Long Lane Farms and west of Long Lane, a small fault was seen to cross the line, having a direction a little north of west and south of east, and a downthrow to the north, the position of the Woolwich Shell-bed being some feet lower on the northern than on the southern side of the line. Between Long Lane and Threecorner Wood there were on the average about 16 or 17 feet of Blackheath Pebble Beds above 13 or 14 feet of Woolwich Beds, the greenish or yellowish sands beneath the shell-bed being more or less visible towards the bottom of the cutting. Where the line crosses Threecorner Wood there was much slipped ground, owing chiefly to the presence of small faults. Towards the eastern boundary of Conduit Wood the cutting is succeeded by an embankment based upon Thanet Sand, and there are no more sections along the course of the new line, which joins the older one about midway between Erith and Dartford. The party walked along this embankment as far as the road on the eastern side of the wood called the Neck, in order to see a denehole in the Thanet Sand at the foot of the northern slope of the embankment, and a few yards west of the Neck. Then, either by way of Northumberland Heath or of Perry Street, the road to Erith was taken in order to catch the 8.38 train for London.

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EXCURSION TO BASTED AND IGHTHAM.

SATURDAY, 24TH JUNE, 1893.

Directors: W. J. LEWIS ABBOTT, F.G.S., AND E. T. NEWTON, F.R.S., F.G.S.

(*Report by* W. J. L. ABBOTT.)

OWING to a misunderstanding as to the times of the trains, the members of the Association travelled in two parties. The first was joined by Mr. Abbott and the Kentish contingent of the Association at Sevenoaks, thence continuing the journey to Wrotham. Here the station yard has been excavated out of the Folkestone beds of the Lower Greensand. These beds are also worked for sand in pits adjoining to a depth of over fifty feet. The sand is of medium fineness, almost white, in places quite so, in others very prettily pseudo cross-bedded with iron-stainings. Nearer Sevenoaks the iron forms a large part of some of the beds. The upper twenty-five feet of the Folkestone beds near the London, Chatham, and Dover Railway at Sevenoaks contain large quantities of well-silicified sponges, echinoderms, and casts of bivalves. The Wrotham sands contain no fossils. Near this station, resting upon the Folkestone sands, is a bed of gravel about four feet thick, belonging to the Shode. At this the first halt was made, and the composition of the gravel notified. Mr. Abbott pointed out where he had discovered an ancient burial, and in the same urn with the burnt bones he had found a piece of the handsome Oldbury-stone, which had also been burnt, suggesting that it had been used as a talisman by the old Neolith.

A much needed shower (after over a hundred dry days) necessitated taking shelter in a large cart-shed near at hand. While the party refreshed themselves with strawberries and cherries and the soothing weed, the directors explained the features of the country to be traversed, and the nature and contents of the fissures to be visited. It was pointed out that in order to realise the significance of the drifts and deposits to be visited that afternoon, it was necessary to understand the solid geology of the district, and the peculiar manner in which it was stratigraphically circumscribed. They were then about 300 feet above O.D., on the dip-slope of the Lower Greensand, which rose to the south to over 600 feet, orming a counterscarp separating the locality from the Wealden district. To the north the Folkestone beds were succeeded by the Gault, which occupies the lower parts of the Holmesdale Valley, the Upper Greensand being questionably represented. Above these rises the Chalk escarpment, which towers to a height of nearly 800 feet. Although the flints make their appearance in the upper part of the escarpment, the main mass is not reached until one has traversed the plateau for a mile or two.

This plateau is of extreme interest from the deposits which now are found upon it, and about which so much confusion exists. The greater part of these deposits had been put down as "Clay-with-flints," which some maintain to be the insoluble residue from the Chalk, left on the removal of the carbonate of lime by solution. But it was pointed out that the advocates of the theory had admitted the insoluble parts to amount to only a small percentage of the rock, while a well has shown thirty-five feet unbottomed of this remarkable deposit—a thickness which on this hypothesis would necessitate a prodigious former thickness of Chalk. Moreover, the matrix is by no means always a clay, but rather a sandy-clay, or even sand; nor, indeed, are either matrix or the accompanying and associated materials constituents of the Chalk, comprising, as they do, erratics of both Northern and Southern origin, as well as the peculiar "old brown" and other flints, which have been altered by a deposit, which Mr. Abbott regarded as of Crag age, similarly changed flints being found in Crag gravels in East Anglia. The peculiar point of interest in this deposit is that flints have been worked (in a rude, though unmistakable, manner) before they entered it, since their worked surfaces have undergone the same molecular changes as the unworked flints. It was also pointed out that the deposit has effected other remarkable metamorphoses upon implements, one being similar to that which transformed the flints in the Crag to the Aldborough variety of Egyptian jasper. All these, together with other Pliocene and Eocene beds, help to make up the materials which now exist upon the plateau, and all of which, in a derived form, go with the Gault and Lower Greensand *débris* to make up the gravels they would see in the Shode and adjoining country.

The points on the watersheds which separate the Shode from the adjoining streams do not exceed 320 feet, so that no gravels much above this height can be ascribed to the valley under the existing *régime*. Yet in this valley we have implements of the older palæolithic types. A few years ago this river had furnished no other fossils to assist in fixing the age of the implements; since then Mr. Abbott had found a few, but these were insignificant compared with the remarkable contents of the fissures to be visited, the position of which at the juncture of the Shode and two of its tributaries, together with their contents, mode of deposition and structure, point to their having been filled by the river during its earlier history, thus furnishing a key to the age of the valley beds. But in addition to the gravels of the Shode, there were others to be traversed at greater heights, which contain a set of implements ruder than those of the valley, which Prof. Prestwich has named the hill group, thus carrying man a step further back. And yet again we had another set of still ruder implements, the "old browns" derived from the plateau. A full description of these, however, was left for a future occasion, when a visit will be made to the plateau. A short account of the rock shelters of Oldbury then in sight was also given, and the implements they yielded described. Thus there was evidence of five distinct periods of man's existence in the neighbourhood. *

5. THE NEOLITHIC MEN, whose implements are spread about the surface of the whole country, never penetrating more than a few inches into the ground, except in the case of hill washes.
4. THE LATE PALÆOLITHIC MEN of the caves or rock shelters.
3. THE VALLEY MEN, in gravels deposited by rivers whose valleys still exist, and which were probably responsible for the filling of the fissures.
2. THE HILL MEN in drifts which were deposited before the existing *régime*.
1. THE OLD PLATEAU MEN, which take us back to a still greater and, at present, unknown, antiquity.

Mr. E. T. Newton then proceeded to give some account of the contents of the fissures, pointing out that we have here the large mammalia—mammoth, rhinoceros, bear, etc., together with several small mammals of Arctic species, which, being extinct, at least locally, are regarded as essentially Pleistocene; but in

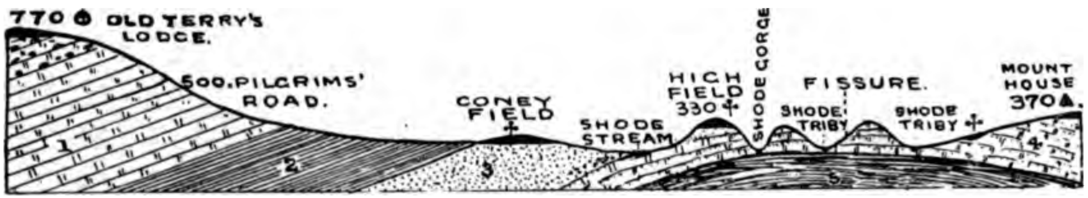
* Since the date of the excursion important discoveries of probably another race have been made, which connect various isolated discoveries. The actual encampments of these have been found in the chert rubble, a deposit accumulated under extremities of cold climate, when the solid rocks were split to small fragments several feet deep.—W. J. L. A.

addition to these have been found a number of other forms: land and water-voles, bats, birds, and frogs, which exist in the neighbourhood to-day. The questions, therefore, which present themselves, are: Were the animals of the former group carried into the fissure first, and the others subsequently? or have we a right to challenge the claim of the second group to Pleistocene age, on the ground of their not having been found before in beds admittedly of that age? The first question, or perhaps both, would be decided by the structure and features of the fissures, the material filling them, the condition and mode of deposition, the state of preservation of the bones, and the manner they were disposed in the material. With regard to most of these factors, they would have an opportunity of forming an opinion when they visited the fissures. He could state that the bones as a whole presented no difference in their extent of fossilization, nor presented any features indicative of a different age. At first he had kept the bones from the various heights and positions separate, but, after a careful comparison of a large number of bones, he found nothing to justify him in regarding those from the various positions, or belonging to different species, as of different ages. The amount of material was very large, some of the bones exhibiting some interesting differences from existing species, forming varieties which were either local or ontogenetic.

The party were then joined by the second contingent, who had travelled by the later train. The fissures were next visited, and some of their contents eagerly scanned by a large number of members, most of whom succeeded in securing some spoil, which included a small jaw, teeth, bones, etc. The physical features of the country, and the fissures, and the matchless quality of the Ragstone were pointed out by Mr. Abbott, Mr. Newton again giving a short account of the contents of the fissure, for the benefit of those who had come down by the later train. Mr. Pink, the lessee of the quarry, being present, Mr. Abbott asked the Association to accord him their thanks for the great assistance he had given, not only in allowing Mr. Abbott to work in the quarry to the great interference of the work of the men, but for having ordered his men to wheel away a great quantity of material, upon which Mr. Abbott had been almost daily engaged for the last two years. The members responded heartily to this request.

A visit was next made to Mr. B. Harrison, at Ightham, who had arranged selections from his collection of implements, now numbering some 2,500, in illustration of the groups previously described. Twenty-seven years ago, Mr. Harrison first led the Association, and twice since its members have visited him. On the occasion of the first visit the Rock-shelter men were in the "prophetic stage," and not accepted as scientific facts, but now things are changed, further excavations having brought to

SECTION FROM THE CHALK PLATEAU THROUGH THE FISSURES TO MOUNT HOUSE BOROUGH GREEN (DISTANCE ABOUT 3¼ MILES).—*W. J. Lewis Abbott.*



● Plateau Implements. ▲ Hill do. ✢ Valley do.

1. Chalk.
2. Gault.
3. Folkestone Beds.
4. Hythe Beds.
5. Atherfield and Weald Clays.

The other numbers indicate altitudes.

The Section is nearly N. and S. till it reaches Coney Fields; it then turns nearly eastward, and after passing the last tributary of the Shode bends round slightly towards E. and by N. so as to bring in the high ground, and the hill group of implements. The dip is made too great, so that 2 and 3 are relatively too thick. Mount House is on Folkestone beds. For Map of the District see Prof. Prestwich, *Q.J.G.S.*, vol. xlv, Pl. ix (May, 1889).

light an immense hoard. The Plateau men were then admitted with even less toleration! This state of things, too, is changed. On the plateau we have implements of the nature of which no one doubts, and of the roughest and rudest of them Mr. Harrison remarked: "If they do appear to bear the work of man, and can be shown to be so selected as to be grouped into various types, each of which types, however rude, is illustrated by numerous specimens—showing how natural flint pebbles of suitable form have been selected, and by being chipped on *one* side only have been brought to the required shape and edge—then I may be justified in having so persistently carried on the work of bringing to light man's first essays in handiwork." That these conditions do obtain cannot be denied by anyone who makes a few hours' study of them. No one could be expected to accept some of these at first sight, except in a series, where their true nature is self-evident. Naturally, as we descend into the border land of nature and art, we find a debateable territory, which requires great care and unbiassed consideration to delimit. Still, the powers of nature, or rather the vicissitudes of gravel making, have a limit.

About sixty of the party afterwards adjourned to the *George and Dragon*, where tea was served. A hearty vote of thanks to the directors, proposed by Mr. T. V. Holmes, brought a very pleasant afternoon, amid scenes of beauty and interest, to a close.

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EXCURSION TO ABINGER.

SATURDAY, 8TH JULY, 1893.

Director: THOS. LEIGHTON, F.G.S.

(*Report by* THE DIRECTOR.)

IT is somewhat surprising that the interesting country of Leith Hill is so little known to geologists. It is true the Association has on more than one occasion visited the southern point of the hill, but the sections around Abinger, which display the structure of the district so well, have not hitherto been the scene of an excursion. Further, there is no full published description of the geology of the district, in many ways so rich in illustrations of physical geology. The only noteworthy account will be found in Dr. Maybury's report on the excursion to Leith Hill and Dorking in 1880,* but as it is clear from that paper that the Abinger sections were unknown to the writer, it appears simpler in the present instance to preface this report with a short general description of the physical geology of the country.

The great mass of Leith Hill is composed of the Hythe Beds, which are probably between 200 and 250 feet thick at the tower. The normal dip of all the beds of the Lower Greensand of this area is to the north, and the surface slopes away in the same direction. For about the first mile, travelling northward, the slope of the ground is greater than the dip, so that lower horizons are found at the surface; then, for about another mile the slope of the ground and the dip of the beds are approximately equal; on the northern flanks of the hill, however, from the latitude of Abinger northwards, the slope of the ground is less than the dip, so that higher beds, the Bargates and Folkestone Sands, are found at the surface. The dip is not permanently to the north, however, and there is evidence of considerable disturbance besides. Within the three and a-half square miles which comprise the district, the map of the Geological Survey shows no less than five small faults, besides the large "Rookery" fault bounding the area on the north. In the hollow lane east of Abinger Hatch, south of the small village of Wotton, the dip varies for some distance between south and horizontal, and is very rarely north; a sharp dip to west is seen in two places north-east of the small fault near Collickmoor Farm, and just south of Abinger Mill there is a small anticlinal fold, cut across by the hollow lane. The drainage of the area is to the north, along the slope into the vale of Holmesdale, whence the waters flow east by the Pipp

* *Proc. Geol. Assoc.*, vol. vi, p. 393, and *Rec. of Exc.*, p. 90.

Brook into the Mole, and west by the Tilling Bourne into the Wey, to be reunited later after many wanderings in the valley of the Thames. By the ordinary process of denudation this northern slope has been deeply scored into valleys, running generally north and south, and separated by distinct ridges uniting to form the southern escarpment. At the bottoms of the three most important valleys the Atherfield Clay is touched, and in the easternmost valley, that of the Pipp Brook, the Weald Clay is twice exposed, upon each occasion to be almost immediately cut off by a small fault bringing down higher beds to the north. The ridge to the east of this valley, known as Ridland Hill, should, for purposes of physical geology, be considered as part of Leith Hill, in spite of the fact that the next ridge to the west, extending from the Warren Plantation by the high ground above the Rookery to the neighbourhood of the Wotton Hatch, forms the water parting between the drainage systems of the Mole and the Wey. Geographers doubtless consider that a good reason for giving this eastern ridge a separate name; geologists will observe, however, that it differs in no way from its fellows except in that the valley on its western flank has been further denuded. There is evidence that the Bargate Beds were formerly widely spread over the area of Leith Hill; how far they were laid down to the east, however, it is difficult to say. The old gravels of the Tilling Bourne, now worked near Abinger Mill, are full of wreck of the Bargate Beds, which must have been brought from the slopes of Leith Hill. The beds are still seen *in situ* along the northern margin of the hill in Raikes Hollow, in Abinger Lane, and in the upper part of the hollow lane east of Abinger Hatch. However, since the most easterly known exposure of the Bargates, the section near the entrance to the Rookery (north of the fault), lies about due north of Leith Hill Tower, and since, further, east of a line drawn between those points (south of the fault) lower beds only are exposed through the process of denudation, the question as to the position of the thinning out of the Bargates becomes, in this area, almost an insoluble one.

The Folkestone Sands probably at one time covered the whole district; they are sharply cut off by the Rookery Fault to the north, and outliers occur on the northern flank of the hill, that to the north of Abinger Hatch showing a junction with the Bargates.

The afternoon of Saturday, July 8th, was one of the hottest of a very hot summer, so that it was found advisable to omit the sections at the top of Leith Hill. From Gomshall Station the high road was taken (eastwards) to the Crossways, then, after crossing the Tilling Bourne, a halt was called at the gravel pit, 330 feet O.D., hidden in a wood at the junction of Raikes and Abinger Lanes.

This gravel is very interesting; it is clearly an ancient gravel of the Tilling Bourne, although it lies much above the level of, and at some distance from, the present stream; nevertheless, geologically, it must be of very recent formation, since flints are so rare that the small fragment found by Mr. Monckton on the occasion of this excursion is probably the first recorded. This absence of flint proves obviously that at the period of the deposition of the gravel every vestige of the chalk covering, and drift derived therefrom, had been removed from the area. It is interesting, for a time estimate, to compare this gravel with that above Farnham at 360—380 feet O.D. (visited by the Association on May 13th last*), which contains rolled palæolithic implements, and is almost made up of flints, the obvious deduction being that the Tilling Bourne gravels must be the more recent, although it does not absolutely follow that they are so. The section in the pit above the Crossways shows much drift stratification, and this patch of gravel is the most easterly of a line of similar patches running parallel with the present stream; there can be little doubt, therefore, that the origin here assigned to the gravel is the correct one. A still more interesting feature is the quantity of Bargate material contained in the gravel (small pebbles, lydites, etc.), which must certainly have been brought from the siopes of Leith Hill.

The Crossways section shows from 8 to 10 feet of gravel (not bottomed), and may be generally described as consisting almost exclusively, if not entirely, of local Lower Greensand material, containing angular and sub-angular fragments of Hythe Sandstone, and Lower Greensand chert, small Bargate pebbles and lydites, and rounded ironstone blocks; the marked current bedding encloses beds of fairly coarse sand, and there are beds of coarse sand and small pebbles, and rough masses of larger material. The gravel from this pit is extensively used for local road-metal.

Proceeding south by Raikes Lane, the Hythe and overlying beds are seen from time to time in the left-hand bank; the calcareous Bargate Pebble Beds first appear a little north of Raikes Farm, at about 430 O.D. Raikes Hollow is about 100 yards farther on, and here, on the right hand, at about the level of the B.M. 462, is seen a bed of stratified pepper-and-salt-coloured glauconitic sands, *not calcareous*, with clayey partings and a 6-inch bed of rotten sandstone with much glauconite, also non-calcareous. The Pepper and Salt Sand is seen in other places in the area in the same position, therefore it is now said to be the top bed of the Bargates here, for reasons which will afterwards appear. Below are the well-known calcareous Pebble Beds of the Bargate Series, passing down into calcareous sands and sandstones, very like the Hythe Beds at a passing glance; so like them, in fact, that it is well to test with acid before defining

* *Proc. Geol. Assoc.*, vol. xiii, p. 74.

them. The Bargate Beds have generally a dirtier appearance, however, and the black pockets of ironey matter, to which attention was drawn in the Hythe section near Wotton Hatch last year,* although universal near the surface in the Hythe Beds of this area, never occur in the Bargates. The junction between the Bargate and Hythe Beds can be made out without difficulty; it is close to one of the telegraph posts on the right hand, and a bed of iron sandstone of Hythe character, a few inches thick, will be found to divide the calcareous from the non-calcareous beds; this is the junction. Below are the typical Hythe Sands and Sandstones of this district, fully described recently.† These are the upper beds of the Hythe only, lower down thick beds of greensand and chert occur, and at the bottom of Raikes Hollow this horizon appears to be touched. The Bargates may be taken as about 40 feet thick in Raikes Hollow, all the beds there dipping north.

Crossing the valley at Sutton and proceeding south towards Felday, there is a small opening in the Hythe Beds under Cony Wood which shows one of the thick beds of chert. At Felday itself there is sufficient evidence of the Atherfield Clay, although no very good section is now open.

A foot-path through Pasture Wood leads to Abinger Common, which was safely reached by the excursion party, but in crossing that common, in the hurry, a wrong path was taken, and when the locality had been identified time would not permit of the visit to the Hythe section above Abinger Bottom.

This section is on the 700 feet contour and shows 14 feet of the Hythe Beds as seen in Raikes Hollow (Rubbly Sandstones), resting on 10 feet of the Massive Sandstones —drab glauconitic sandstone of massive structure with black iron staining in the fracture joints. These beds are possibly the same as the lower beds under the tower at the summit of Leith Hill; they weather red and become softer from exposure if that surmise is correct; *beds* of stone of this character are seen near Collickmoor Farm on Ridland Hill and elsewhere; the lower horizons sometimes contain thick beds of chert; these appear to be of uncertain occurrence, however.

After tea at the Abinger Hatch the return route was commenced by Abinger Lane, where there are several sections.

On the left hand side, a short distance from the stocks, the Pepper and Salt Sands of the Bargates are seen. Further on the Folkestone outlier is reached with typical and unmistakable sections on both sides of the road. Immediately adjoining that, on the left hand, is a second pit showing an extremely interesting junction with the Bargate Beds. Below typical Folkestone Sands come false-bedded sands with thin clayey beds, displaying a remarkable

* *Proc. Geol. Assoc.*, vol. xii, p. 403.

† *Proc. Geol. Assoc.*, vol. xiii, p. 7.

admixture of different kinds of sand in the false-bedding, beds approaching Folkestone character are dovetailed into beds of pepper-and-salt-coloured glauconitic sands of Bargate character and *vice versâ*. The Pepper and Salt Sands are coarse and contain "lydites," many of them very light in colour, and flakes of iron oxide (or possibly phosphate); clay beds occur at intervals, sometimes three inches thick, whilst a thin layer of clay usually follows the lines of differentiated sands in the false-bedding. These beds settle down into the darker (more glauconitic) Pepper and Salt Sands with clayey partings and beds of grit, which have been described above as the top bed of the Bargates. All these beds dip north, and are non-calcareous. There is a perfect passage shown from the Bargate to the Folkestone Beds in the three sections at this place.

Just beyond, to north, the road makes a sharp dip, but there are no sections; nevertheless it may be fairly said that this is occasioned by the outcrop of the hard beds of the Bargate Stone. Further on the road makes another dip, and there the Hythe Rubbly Beds are seen in the bank on the left hand; still further, on the right, drift is seen over Hythe Beds. Still further, just before the road turns to right to the mill-pond, the Hythe Beds are seen on the left hand dipping south; this phenomenon is explained, however, at the turn, where, on the right hand, a small anticlinal fold is intersected by the road. A very instructive section is shown, although it cannot be said that the feature is of much importance beyond being an illustration of the disturbances occasioned by the high elevation of the same beds at the summit of Leith Hill. With the Hythe Beds raised to a height of 965 feet O.D. immediately to the south, it is somewhat surprising that more evidence of disturbance is not forthcoming over the area where the surface level begins to become normal. No doubt the great "Rookery" fault with its throw to north of 100 feet acted as a safety valve; still possibly this little anticline also illustrates a reason for the absence of much evidence of disturbance, since the beds are here shown to be extremely flexible. The axis of the fold lies approximately N.N.W.—S.S.E., and the whole dips in the latter direction. The arch of the fold as seen in the section is quite perfect; there is no fault, but a bed of white sandstone shows several pretty disrupted fractures at the top of the arch, whilst softer beds and a piece of false-bedding are beautifully bent over without apparent break.

A short distance from this point the route joins the outward one which has been already described.

EXCURSION TO THE COUNTIES OF DUBLIN AND WICKLOW.

MONDAY, 24TH JULY, TO SATURDAY, 29TH JULY, 1893.

Directors: PROF. W. J. SOLLAS, D.SC., F.R.S., F.G.S., AND PROF. GRENVILLE A. J. COLE, M.R.I.A., F.G.S.

(*Report by* PROF. COLE.)

THE headquarters of this excursion were throughout established in Dublin, most of the party putting up at Morrisson's Hotel. Some twenty members having arrived as early as Sunday, July 23rd, they were invited on the morning of that day to the Royal Botanic Gardens, Glasnevin, by Mr. F. W. Moore, F.L.S., the curator. In the afternoon they were met by Rev. Denis Murphy, S.J., M.R.I.A., who conducted them through the older portions of the city, including the two cathedrals, and afterwards to the Phœnix Park, whence an admirable survey of the Dublin and Wicklow mountains, from the Sugarloaf to Blessington, can be obtained. During this preliminary day the members thus became familiar with their surroundings, preparatory to the geological expeditions of the week.

Monday, July 24th. The sequence of the excursions was regulated mainly by the tides, which were favourable for shore walking in the earlier portion of the week; but the opening visit was appropriately made to the oldest rocks of the district. Few Irish place-names are more familiar to geologists than Bray Head, owing to the controversy that has arisen over *Oldhamia*; the structure known by this name is, moreover, figured in most of the text-books. Allowing time for those members who had travelled on Sunday night to become somewhat rested, the party left Westland Row station for Bray at 10.45 a.m. Permission having been previously obtained for crossing the railway on Bray Head itself, the members were guided by Prof. Sollas to the Periwinkle Rocks, after ascending the cliff-path for some distance. The contrast of the glacial "Sands and Gravels," here represented by a coarse boulder-drift, resting on the folded Oldhamian grits and slates, is a particularly fine one on the descent to the shore. *Oldhamia radiata* was freely collected on the rock-ridges running out to sea. Several members discussed the mammillated surface of a grey-green grit-bed that here forms one wall of a shallow cave, rising from the beach. Prof. O'Reilly directed attention to it, the curvings having the appearance of a flow-structure, and forming, in fact, a common feature of the surfaces of the grits across the Head. Prof. Sollas attributed the mammillations to original conditions of deposition, the sandy material filling up irregular hollows of the shore, and being subsequently deformed by the general movement of the district; others thought they were the surfaces of kidney-shaped bodies, such as arise sometimes by contraction. Prof. O'Reilly subsequently pointed out other examples, stating that we faced here only one of the many problems of Bray Head.

On regaining the level of the railway, Rev. Samuel Haughton, M.D., F.R.S., who accompanied the party for most of the day, gave a short address of welcome to the Association on the occasion of its first visit to Ireland. This was replied to by Mr. T. V. Holmes, vice-president, and Mr. Jas. Parker. Prof. Sollas also described the main features of the headland, the cliff-sections of which were then visited by means of the excellent path above the line. Evidence of contorted flow of the once plastic clays between the more resisting grit-bands was beautifully seen at several points.

Returning from about the summit of the path, the members were free to admire the landscape across Killiney Bay, from the steep sea-inlets of Bray Head itself to the spurs of granite at Killiney, with Dalkey Island in the foreground, and the old rocks of Howth beyond. On the left, the *massif* of the Leinster granite could be seen, with the Carboniferous plateau abutting against it to the south of Dublin city.

Prof. Sollas and three or four adventurous members found time to ascend to the quartz-rocks on the summit of the headland, and rejoined the party at Bray station, their arrival in time being assisted, it must be admitted, by the *genius loci*, an Irish car.

Then train was taken across the drift-covered hollow to Killiney station, where the party examined the cliff of "sands and gravels," containing scratched blocks, on the beach immediately to the south of the station. The pebbly strand was then traversed to the northern end of the bay, where the first rocks encountered *in situ* show granite intruded into Ordovician shales, which are here altered into Andalusite-mica-schists. The first bluff consists of granite, with a mass of schist wrapped round by the igneous rock, as may be seen upon its northern side. A little farther north the intrusive junction is excellently seen, dykes and veins of the granite penetrating the schists in all directions. The occurrence of the knots and stellar groups of Andalusite in special bands in the schists was also pointed out. Some garnets and true chiastolite were discovered, and also, in the shore-pebbles, some large pink andalusites.

The party became somewhat scattered after crossing the iron foot-bridge over the railway, and climbing towards the road on the sea-front of the hill; but all reassembled on the summit of Killiney Hill, which is now converted into a public pleasure-ground, under the title of Victoria Park. Prof. Cole pointed out the features of the fine and varied landscape, which included almost all the spots to be visited during the week. At the kind invitation of Prof. and Mrs. Jas. Lyon, the members took tea at Plas-newydd, which is beautifully placed on the slope above Kingstown harbour. Dublin was reached by the train leaving Dalkey station shortly after 7 p.m.

Tuesday, July 25th. The weather again favoured the expedition throughout this day's visit to Portrane. Amiens Street station was left at 10 a.m., the party alighting at Donabate. A walk of two miles or so brings one to the coast, at the south side of the estuary that divides Portrane from Rush. The "Old Red Sandstone," the basal conglomerate of the Carboniferous system, crops up in little purple bosses in a field close to Donabate station, and is also the first rock encountered on the coast. On the way the members were joined by Mr. M'cLoughlin, a resident in the peninsula, who guided them to the old church and castle, and kindly accompanied them throughout the day.

Following on the Old Red Sandstone, a mass of dark purplish and greenish ashes is exposed, which belongs to the underlying and unconformable Ordovician system. Going east, and facing the great volcanic centre of Lambay Island, the rocks became more conglomeratic, and lumps of lava and limestone were seen mingled together in them. The lowest part of the Bala series as here exposed is a mass of limestone containing numerous silicified fossils, especially corals. The spot may be found by observing the massive character of the limestone beds, which are jointed into cuboidal blocks, and are finely contrasted with the alternating nodular limestones and shales immediately to north and south of them.

At the next inlet, Mr. McLoughlin led the way down to a spring in a sea-cave, known as the Priest's Cave; and those of the party who descended were rewarded, not only by the water, but by a good example of the brecciation to which these rocks have been subjected. On the north side of the mouth of the cave the alternating limestones and shales are seen in their true relations, reminding one of similar series in the Carboniferous or the Jurassic systems; but on the south side they have been broken up, the limestone blocks have been floated about in the more yielding shales, and the mass resembles a conglomerate of limestone in a black argillaceous cement. Similar features are frequent at this corner, together with delicately curved surfaces and contortions.

The south end of the promontory is a mass of sand-hills, stretching away to the narrow strip of water that divides Portrane from Malahide. The party examined the recurrence of igneous rocks just short of the sand-dunes, and then turned westward to Donabate, crossing a boss of Old Red conglomerate in the Portrane demesne. The low cliff of glacial drift, full of striated pebbles, was observed as the shore was left, resting upon smoothed surfaces of Ordovician shale and limestone.

From Donabate the members reached Dublin before 4.30, this excursion being the easiest of the six proposed. The indented coast, with its little rocky coves, the fine mass of Lambay Island, green and purple in the sunlight, and the broken outlines of Howth and the Wicklow mountains in the south, made, however, the expedition a charming one, and quite distinct in scenic character from those on the other side of Dublin.

From Amiens Street station the members walked direct to Trinity College, where, guided by Prof. Sollas, they entered the Library. The famous manuscript, the Book of Kells, was for once removed from its glass case for more adequate inspection; and the other treasures of Early Irish art and literature were examined. The large geological museum, the College buildings, and several of the laboratories were subsequently visited.

Wednesday, July 26th. In a brilliantly sunny morning, a party of forty set out for Howth, leaving Amiens Street station at 9.45. Mr. G. H. Kinahan, M.R.I.A., was present in addition to the directors, and the members were joined later in the day by Dr. Valentine Ball, F.R S., and Mr. A. B. Wynne, F.G.S.

The train was left at Sutton, and Prof. Sollas led the way to the dolomitised Carboniferous Limestone on the south side of the neck of the peninsula. The contrast between the brown altered rock and its blue-grey unaltered condition is here well seen, and the dolomitised portions have frequently developed parallel shrinkage-cracks, in which calcite crystals have arisen.

The drift, resting on striated surfaces of limestone and older quartzite, was also studied along the shore.

The path then leads across characteristic bosses and promontories of the quartzite of the Howth and Bray series, until it rises along the crest of the cliffs, with the heather-covered slopes of the Hill of Howth still above upon the north. The tide not being yet low enough for the shore-route to be taken, Prof. Sollas descended with some of the party directly to the Needles, which are isolated sea-worn masses of the quartzite resting on a sheet of intrusive porphyritic andesite, probably of Ordovician age. A similar dyke, weathering into a soft brown clay, had been inspected a little to the west.

Prof. Cole and the remainder of the party—with the exception of a few who lost themselves on the heathery expanse above—descended into the fine bay between the Needles and the Bailey Lighthouse, and examined the vertical grits and shales. The cliffs here are remarkable for a delicate variety of colour, grey-green, purple, pink, and pale orange. A conspicuous fault in these folded strata has been figured in the Survey Memoir.

After one or two vain attempts to communicate with the detachment on the other side of the headland, lunch was taken placidly; and presently a photographer appeared, wading round boldly with all his impedimenta, and followed by other adventurers. Prof. Sollas, who had selected the most difficult route, pointed out some dark tubular bodies in the sandstones at the west angle of the bay, attributing them to the action of worms, which, indeed, seems their only explanation.

Meanwhile, several members paid a visit from this side to the Needles and to the igneous sheet. Mr. Alcock, of Dublin, climbed the larger Needle on this occasion; but the enthusiasm caused by this event was surpassed when a careful wader was seen to drop both his boots and stockings into one of the slippery sea-pools.

Proceeding to the enclosed area in which the Bailey Lighthouse stands, the remains of ancient hearths were examined, the black patches of charcoal being revealed by the cutting of the road. A kitchen-midden, with abundant lumps of charcoal, and bones split for the extraction of the marrow, occurs on the steep slope between the lighthouse road and Dublin Bay. Successful collecting was done here, Prof. Sollas explaining that the material had probably slipped over from above.

The cliff-path was then taken to Howth village, above a succession of steep inlets in the slates. The Ordovician rocks and older quartzites on Ireland's Eye were pointed out; beyond this island lay Lambay and the promontory of Portrane; while the Tertiary masses of Slieve Gullion, Carlingford, and the Mournes could be seen distinctly, their serrated outlines ending in Slieve Donard, sixty miles north across the sea.

Just where the path begins seriously to descend towards the large quarry, the brecciated condition of the quartzite bands in the shales and slates can be excellently noted, the crushed rock having almost the appearance of a conglomerate.

At six o'clock the party assembled in the St. Lawrence Hotel at Howth, at a dinner given by the geologists of Dublin. Dr. V. Ball occupied the chair, and the cordial sentiments of all parties broke out into the toasts of "The Queen," "The Geologists' Association," "Trinity College," and "The Dublin Geologists." It was past 10 p.m. when Dublin was reached by rail, in a calm and moonlit night.

Thursday, July 27th. Taking advantage of the ordinary excursion arrangements of the Dublin, Wicklow, and Wexford Railway, the members left Harcourt Street at 8 a.m. for Rathdrum, a distance of some 36 miles, and drove to Glendalough on the cars which are run in connection with the train. The railway skirts the northern end of the Leinster chain, under the granite tors of Three Rock Mountain, traverses Bray Head by a striking series of viaducts and tunnels, and then runs along a plateau of drift, which the sea is constantly attacking. After Wicklow it turns inland, and passes the fine quartzite ridge of Carrick Mountain, comparable in form and age to the Hill of Howth. Rathdrum itself is built on the Ordovician foothills of the Leinster chain, which contain numerous contemporaneous igneous rocks.

The road to Glendalough ascends the beautifully wooded valley of the Avon Beg, amid scenery reminding one of the finest parts of Devonshire. At Laragh it crosses the Military Road from Dublin, a walk or drive along which is a superb introduction to the mountains; this route is now, however, practically restricted to cyclists, and to such of them as prefer scenery to record-breaking.

The party halted at the Seven Churches, in the midst of the "Glen of the two lakes," and some time was spent in examining the Round Tower, and the unique remains of St. Kevin's Monastery, founded in the seventh century. The members had certainly exceptional opportunities on this occasion. Rev. Denis Murphy, S.J., had kindly postponed a visit to the south, and had accompanied the party with a manuscript-life of St. Kevin and a history of the churches, extracted from original sources. The reading of these papers in the enclosure itself added great interest to the excursion. Moreover, Rev. Maxwell H. Close, F.G.S., Treasurer of the Royal Irish Academy, was also present, with Mr. Jos. Nolan, Senior Geologist of the Irish Survey, and author of a guide to Glendalough; both these gentlemen were ready to discuss the ruins, and Mr. Close gave some account of Round Towers and their relation to the adjoining churches.

At 1.15 Prof. Sollas led the way up a fir-clad slope beyond Richardson's Inn, leaving those who feared a stiff ascent to explore the Upper Lake and the foliated granite at its head. The ladies who accompanied the hill-men almost deserve mention by name, for the pace was so brisk that a scattering of the party was inevitable. The fir-wood ended in undergrowth and dense bracken, in which the heads of wanderers rose and sank; but only one or two had disappeared when the party reassembled at an exposure of amphibolite, on the high breezy ridge, and the loss of these valued members seemed a matter for mirth rather than anxiety.

This amphibolite is the subject of an investigation by Prof. Sollas, who showed the members how it had produced at contact a new foliation and a new mineralisation in the Ordovician schists. These had previously been altered by the adjacent granite mass, and the amphibolite, passing into diorite, could thus be shown to be the later of the two intrusions, though it was not seen to cut the granite.

Farther west upon the ridge, after a steep descent down a dry water-gully, the junction of schist and granite was visited. The granite is here remarkably foliated, probably in this case by pressure. The whole party met below along the high road, and returned by the lake-side to the Royal Hotel, where dinner was served at 5.45 p.m. In this case the Association entertained the Dublin visitors and the organisers. In the light of a fine sunset the return drive was made to Rathdrum, Dublin being reached soon after 10 p.m.

The press, and particularly *The Freeman's Journal*, had taken very fair notice of the doings of the Association in Ireland; as an example of this, the reporter who had accompanied the party to Glendalough all the morning, and who had returned to his office in the afternoon, reappeared at 10 p.m. on the railway-platform, to obtain the latest geological information.

Friday, July 28th. The day's work was mainly among the glacial deposits, and particularly among those made famous by the observations of Rev. Maxwell Close. Mr. Close accompanied the excursion, and led the way from Carrickmines station, on the line from Harcourt Street to Bray, up to Ballyedmonduff, a house on the slope of Two Rock Mountain, about 1,000 feet above the sea. Here, opposite the house, is the pit, now fallen in and grass-grown, where Mr. Close discovered numerous marine shells of existing species scattered through the sands and gravels. The party obtained several fragments, particularly a fine piece of *Turritella terebra.* Higher up, Mr. Dunne's pits, on the west side of the road to Glencullen village, were examined in some detail, the stratification being well seen in the smaller excavation near the road. Mr. Close related how he had stood here with the late Prof. Carvill Lewis, who had failed to convince him that the shells were pushed uphill, or raised through the mass of an enormous ice-sheet. He himself recognised that the shells were fragmental and not in their original place of deposition; but he believed that the animals had lived, during a recent period of submergence, on what were now the higher levels of the mountains. Prof. Cole, concurring in this view, said that he regarded the rearrangement of the "drift," and particularly the filling up of Glencullen, as due to the action of ordinary mountain-streams; hence even the gravels with marine shells might, in their present condition, be fluviatile.

The party then descended the remarkably steep road to Glencullen Bridge, facing the granite quarries, in which beryl and iolite have been found. These, however, had been omitted from a programme which already covered twelve miles of country. The foot-track starts across the wall on the Dublin side of the bridge, and leads down the glen to Enniskerry, giving a series of pictures of primitive upland country, untouched by road or railway, and within ten miles of the metropolis. The floor of the glen is largely covered with pebbles from the drift, the gravels forming terraces on the north side, and appearing in occasional patches on the south, clinging to the granite wall. The valley has been excavated, has become choked with mountain-detritus, and then has been partially cleared out again, the stream now running on granite near the bridge, and cutting its way deeply between walls of sand and gravel farther down.

The great section in the drift, some 120 feet in height, was a special object of attention. This is an impressive sight when viewed from the level of the stream ; but it can also be reached from Dublin by traversing the Scalp and taking the first road which rises on the right, leaving Killegar church, an overgrown ruin, well on the left. This road winds round to the left and becomes a stony track, terminating at a gate on a grassy plateau, with a fine view of the Sugarloaf beyond. This plateau represents the high level of the material infilling Glencullen, and the visitor, walking across it in the direction of the Sugarloaf, comes abruptly on the glen, and can descend by a steep path to the river.

In the upper part of this section in the drift, large granite boulders are numerous, forming, by their protective action, imperfect "earth-pillars." The gravel is often firmly cemented by carbonate of lime, and striated pebbles of Carboniferous Limestone are abundant.

The path follows the stream closely, and goes finally to Enniskerry through a wood. The Ordovician slates are here reached, and the stream cuts a deep gorge in them at the village. A light tea was obtained at the Powerscourt Arms, and the party proceeded, on cars that were in waiting, through the Scalp to Carrickmines.

At the south end of the fine granite gap known as the Scalp, the junction with the Ordovician slates was seen, the beds being much contorted. In the ravine itself a lively discussion was raised on the merits of Prof. Jukes' and Prof. Hull's explanation, which attributes the valley to the action of a stream rising to the north, on ground which has subsequently been cut away by another system of drainage. Mr. G. H. Kinahan urged that the gap was a shrinkage-fissure, a view that he has since maintained in the pages of *The Irish Naturalist*. The action of the water has taken advantage, as all must admit, of the main joint-lines of the granite—a fact still better exemplified in the valley called the Dingle, a little to the north-east of the Scalp.

The day had again been fine throughout, and a broad yellow sunset spread behind Two Rock Mountain as the cars drove down finally to the station at Carrickmines. After dinner the evening was spent at the rooms of Prof. Cole, music being provided by several ladies, and the gathering proving eminently social.

Saturday, July 29th. At last a few clouds and a few light showers broke the weather of the week, but they only added to the wildness of the long mountain drive that formed the concluding feature. It would be only a partial survey of the surroundings of Dublin if one omitted a visit to the granite ridge itself, which can be reached in seven miles from the centre of the city. To drive from Rathfarnham up the military road and over to Lough Bray would form a fine approach to the area of the lakes; but this day's excursion, planned to include Luggela and Lough Tay, necessitated a start from and a return to Bray. The Dublin Naturalists' Field Club had, two months before, arranged to join in the expedition, and some fourteen members of the Belfast Naturalists' Field Club, who were present in Dublin by invitation, also added interest to the party. The vehicles of the prudent Mr. Ledwidge, of Bray, an excellent manager, thus carried seventy-six persons from the station at 9.45 a.m.—a procession of sixteen cars and a waggonette—and three belated, but enthusiastic, members came up with the main body at Lough Bray. The ascent to the lakes is through Enniskerry and along the valley-side of Glencree, affording a very fine view of the broken country formed by the quartzites and slates of the Bray series. Lower and Upper Lough Bray lie in the hollows of steep granite cirques, at the head of Glencree. Mr. Close had brought a large diagram to illustrate the moraine-dam between the two lakes, and the glacial terraces which fringe the lower one. An hour was spent at this point, and the party then walked along the high moor towards Sally Gap, until overtaken by the cars. Mr. Close stated that the name of this pass means the Gap of the Willows. A sharp rain drift, coming up the valley from Kildare, gave a fine touch to this barren landscape, traversed by the road at a height of 1600 feet. In the boggy ground on the ridge the Liffey has its source, reaching Dublin only after a long detour to the south. The military road, which had been followed from Glencree Reformatory, was left at the Gap, and a brisk descent was made to the hollow of Lough Tay. Even here the road remains a singularly high one, and is seen running along the rock-strewn slope far above the demesne of Luggela. By permission of Mr. Stepney, the party entered the grounds, being met by Mr. Unsworth, who was in charge of the Lodge. The descent was down a steep granite talus, overgrown with trees. The lake lies at the foot of a crag, which has been carved almost along the junction of schist and granite, and the latter is here foliated in an unusually delicate manner.

As the members ascended again by the drive to the high-road, they could see huge granite boulders lying on the Ordovician uplands and standing out boldly against the skyline. A glimpse of Lough Dan, another of these mountain lakes, was obtained at the gate, in the midst of a wild cloudy landscape, probably the finest impression of the day.

Here several stalwart men of Belfast turned off to reach Glendalough on Sunday; four others of the party had returned from Lough Bray, so as to leave Dublin the same evening. But the remaining seventy walked down the somewhat tedious road to Anna Carter Bridge, where the cars were again in waiting. The hills began to be capped with clouds, through which the sun shone in long low gleams across the moorland. The party drove along the shoulder of the Sugarloaf, walked down the steep drop into the Rocky Valley, and reached Bray, having described a complete circle, in time for the train at 8.0 p.m. This was an hour later than had been originally contemplated, but it seemed generally agreed that this final survey of the granite and associated ranges atoned for the thirty-two miles of driving.

Sunday, July 30th. As only a small proportion of the members had been obliged to leave Dublin, Dr. Valentine Ball, F.R.S., arranged a visit on this afternoon to the Museum of the Science and Art Department, of which he is Director. One-half of the collections is open each Sunday, but the Association had the advantage of viewing the geological and antiquarian sections on this occasion privately, the zoological section being that open to the public. Dr. Haughton and Dr. Scharff were also present, and Major M'Eniry, Curator of the Royal Irish Academy collection, explained the unique treasures of early Irish workmanship in his care. The Irish Elks, and the rock-collection of the Geological Survey of Ireland, arranged according to localities under the corresponding maps, received special attention, as did also the geological relief map of Ireland, on the scale of one inch to the mile. Dr. Ball had kindly printed an extract from the guide to the Museum specially for the visit of the Association, so that everyone carried away an accurate reminder of the occasion.

The evening was most pleasantly spent at the house of Prof. Sollas, in Rathgar, where numerous sections of the rocks that had been visited during the excursions were exhibited under microscopes, while music made an agreeable relaxation in the intervals of study.

On the following morning a few members left for England, but the majority continued their excursions unofficially, towards Killarney, the Causeway, or the Shannon.

For references see page 121.

EXCURSION TO THE DENEHOLES OF HANGMAN'S WOOD, NEAR GRAYS THURROCK, ESSEX.

(In connection with the Essex Field Club.)

11TH AND 12TH AUGUST, 1893.

Directors:—T. V. HOLMES, F.G.S., AND W. COLE, HON. SEC., E.F.C.

(*Report by* T. V. HOLMES.)

THE Association visited these pits on May 9th, 1885, and a Report of the excursion is given, *Proc. Geol. Assoc.*, vol. ix, p. 179 (Nov. 1885). On that occasion, owing to the labours of the Denehole Exploration Committee of the Essex Field Club in the previous autumn, the party was enabled to enter 12 distinct deneholes on descending a single shaft. The Exploration Committee continued its work in the autumn of 1887, and gained admission into two more pits, which were unfortunately too much choked with *débris* to be of any use. Sifting operations were also continued. The exploration was brought to a close in October, 1887, after six weeks' subterranean work, and a Report by Messrs. T. V. Holmes and W. Cole, to whom the Committee had entrusted the direction of the work, was published by the Essex Field Club in December, 1887. It is fully illustrated by maps, plans, and sections, and contains, in addition, Notes by Messrs. E. T. Newton, F. W. Rudler, F. J. Bennett, H. B. Woodward, and F. C. J. Spurrell.*

Referring those who wish for full particulars to that Report, a brief summary of the conclusions of its writers may be useful here. Trenches dug in the surface of the Wood showed the great care which had been taken by the denehole makers to preserve the original flattened contour of the ground. The surface-gravel had been carefully spread about and the underlying Thanet Sand diffused evenly over the gravel, while not a single fragment of Chalk could anywhere be seen. This evidently implied a desire to keep the position of the deneholes as much of a secret as possible. Then the separation of each pit, and their concentration in a spot where the Chalk is nearly 60 feet beneath the surface, though there is plenty of bare Chalk within a mile, showed that the object was not to obtain Chalk. The more probable hypothesis that they were flint-mines was also found to have no evidence in its favour. For the exploration showed that

* It may be obtained from Mr. W. Cole, 7, Knighton Villas, Buckhurst Hill, Essex (Price 2/-).

the only conspicuous flint band in the pits had never been worked; and no flint cores, flakes, or implements were found, though many large flints had been used to line the upper part of the shaft, and were conspicuous in the lower portion of the heap existing at the base of each shaft when the exploration was begun.

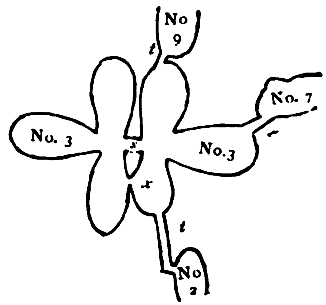
On the other hand, owing to the immense amount of *débris* in each pit, and to the narrowness of the shafts, which prevented the removal of rubbish to the surface in consequence of the great amount of time and expense it would have necessitated, it was possible to reach the floor only in small areas here and there. And as any clue to the antiquity of the pits could be furnished only by objects found on or close to the floor, the bones, pottery, etc., found there were insufficient to establish the approximate age of these deneholes with any approach to certainty. The absence of worked flints seemed to imply a later date than the Neolithic Period, while allusions to them as "King Cunobeline's gold mines," in the time of King Henry IV., show that they were looked upon as works of unknown antiquity and function at the beginning of the 15th century. As to the uses for which they were constructed it seemed most likely that they had been intended to serve chiefly as granaries. Those interested in the subject of subterranean granaries may be referred to Mr. Spurrell's paper on Deneholes in *The Archæological Journal* for 1882, or to that by the same writer appended to the Denehole Exploration Report already mentioned: also to a paper by the present writer "On Some Curious Excavations in the Isle of Portland," *Proc. Geol. Assoc.*, vol. viii, No. 7, p. 404 (July, 1884). In addition may be mentioned a "Note on the use of Pits in Brittany for the Storage of Grain," by Mr. Charles Browne, in *The Essex Naturalist* for January and February, 1888. It is gratifying to be able to state that Prof. T. G. Bonney, in acknowledging the receipt of a copy of the Denehole Report, remarked that he thought our conclusion that the Hangman's Wood pits had been originally used mainly as granaries a very probable one; adding that subterranean granaries resembling them existed in Syria.

It was a matter of considerable interest to the Directors to note the changes that had taken place since the conclusion of the exploration in 1887. For their tunnels had allowed currents of air to pass through many pits previously closed and stagnant. No appreciable change for the worse, however, seemed to have been caused by the ventilating currents, though much harm had resulted from the mischievous stupidity of unauthorised persons who had visited the pits. The visitor to Hangman's Wood from Grays, who walks along the wood skirting the southern boundary of the wood, will pass on the right (or southern) side of the road three of the five open-shafted deneholes. Near them, but north of the road, is another open-shafted pit, the fifth being about 40 yards still further north. The pit near, but north of, the road (called No. 3 in the Report) is that by which hitherto almost all descents have been made. It was our headquarters during the Exploration, and from it we tunnelled in three different directions. We naturally, therefore, had our apparatus for descent fixed over it on this occasion. The lower part of the shaft, however, was found to be full of the trunks of young oak and ash trees, and many more were found in the chambers below, when we at last managed to enter them. In this pit, as in others, the cylindrical shaft through the Thanet Sand had been continued for three or four feet in the Chalk, and then the lateral excavations had been begun. The two primary chambers, as usual, were in the same straight line but on different sides of the shaft, two lateral chambers on each side having been afterwards added, so that the ground-plan of the denehole had acquired the ordinary double-trefoil shape. And the continuation of the shaft from the roof of the chambers to the floor consisted of two masses of chalk, one on each side, six or seven feet broad, and with a space of four to five feet, or thereabouts, between them. In 1887 a visitor standing at the base of the shaft with one of the primary chambers in front of him would have had a massive chalk pillar on his right and another on his left. But in August, 1893, he would have found that one of these massive pillars had been wholly knocked away and that the two lateral chambers nearest to the tunnel leading to the open-shafted pits south of the road (Nos. 2 and 4) had been knocked into one. The massive pillar of Chalk between the shaft (*s*) and a small hole in the partition (*x*) between these two chambers had been wantonly destroyed. The diagram below, taken from the ground plan given in the Report, willl show the amount of damage done to the stability of the pit better than any verbal description. The denehole constructors frequently (as shown in Fig. 3 of the Report) enlarged the available area in a pit by removing most of the partition separating the lateral chambers, but they were careful to leave a massive pillar of chalk close to the shaft on each side in the position of that so mischievously removed. Probably the hurling down of the tree trunks did an amount of damage to the chalk at the base of the shaft which suggested to some stupid intruders that complete destruction might be effected by the use of the trees as battering rams.

Turning to the other side of No. 3, we saw that there was a hole, about three feet by two feet, in the thin partition separating the adjacent chambers of Nos. 3 and 9. This did not exist in 1887, but as the concussions attending the destruction of the Chalk pillar 30 or 40 feet away must have been very considerable, they were, in all probability, the cause of its appearance. It certainly is not a work of design. It is probable that most, if not all, of the holes in the thin partitions between contiguous

DIAGRAM TO SHOW THE DAMAGE DONE IN NO. 3.

(From Plan in Denehole Exploration Report).



No. 3. Denehole descended 11th and 12th August, 1893 (ground plan).

Nos. 2, 7, 9. Adjacent deneholes.

t. Tunnels from No. 3. *s*. Shaft. *x*. Hole in partition between lateral chambers.

Scale:—one inch = 40 feet.

chambers of different deneholes may have been produced in a similar way by concussions arising from the sudden fall of masses of material centuries after the disuse of the pits.

The excavations made during our Exploration in the heaps at the base of the shafts remained unchanged. We at first thought it prudent to tunnel through the Chalk in every case, rather than to trust to a passage made through the Thanet Sand which forms the greater part of these mounds. As the work progressed we ventured on occasional holes through the mounds (where they consisted of compacted Thanet Sand) with satisfactory results.

At the base of the shaft of one of the open-shafted pits south of the road, the five-chambered denehole shown in the circular of the Essex Field Club (No. 2), Mr. Cole found a poor dog in a state of extreme emaciation, but otherwise unhurt. Though it thankfully accepted the meat out of several sandwiches it refused water, an eccentricity, perhaps, to be accounted for by the dampness of the air in the deneholes, and their comparatively low temperature at this time of year. It was stated on Saturday afternoon that the difference between the surface and subterranean temperatures at Hangman's Wood was 23 degrees, a circumstance which caused the eighty persons descending into the pits to feel that the denehole excursion was particularly well timed. The dog was brought to the surface, and when last heard of had continued to make rapid progress towards complete restoration to health.

Captain Whitmore, of Orsett Hall, the owner of the land, who had kindly given permission for our descent, was among those who visited the deneholes on Saturday. This was a very fortunate thing for those interested in the preservation of the deneholes, as he was much impressed by a sight of the damage done by the unauthorised visits of ignorant and destructive boors, and expressed his attention of taking measures to prevent it in future.

ORDINARY MEETING.

3RD NOVEMBER, 1893.

The President, HORACE B. WOODWARD, F.G.S., in the Chair.

The donations to the Library since the previous meeting were read, and thanks were accorded to the several donors.

The following were elected Members of the Association :— C. E. Dillon ; Mrs. Emma Smith ; D. W. Buxton ; J. H. Fawcett ; W. Fraser Hume.

The Meeting then resolved into a Conversazione. The chief objects exhibited were :—

Variolites from Wales, by Miss Raisin.

A series of Implements from the Plateau Gravel, to illustrate the Excursion of the Association to Sevenoaks, by W. J. Lewis Abbott.

Micro sections of Quartz, showing perlitic structure, and other rock sections, by W. W. Watts.

Specimens collected on the Excursions of 1893, by H. W. Monckton.

Illustrations of some new fossils discovered during 1893, by Rev. Prof. J. F. Blake.

An *Ichthyosaurus*-paddle from Barrow, showing integument, and various photographs illustrative of Excursions to Norfolk, Dublin, and Wicklow, by Hy. Preston.

A series of Ammonites, from the Lias, by H. B. Woodward.

Labradorites from Volhynia, and ores from Ekaterinburg, by Dr. W. Fraser Hume.

A cast of the head of *Elginia*, and other casts of Reptilian remains, from the Triassic Sandstones of Elgin, by E. T. Newton.

Micro-sections of rocks, mostly Alpine, by Geo. Smith.

Photographs of scenery in the Higher Alps, by J. W. Reed.

Index-maps of the Geological Survey of Great Britain, by W. Topley.

Micro-sections of rocks containing Radiolaria, by Dr. Hinde.

Neuropteris from the Forest of Dean, fossil plants from Greenland, and Ammonite-rock from Marston Magna, by W. F. Gwinnel.

Eocene Fossils, from the Paris Basin, by T. W. Reader.

Specimens illustrative of the High Level Gravels round London, by A. E. Salter.

A series of Chalk Fossils from Margate and elsewhere, by F. R. B. Williams.

A series of Flints, showing peculiar internal structures, from the Croydon district, by G. Abbott.

Ten specimens of Silicified Corals, from the Carboniferous Limestone of North Staffordshire, developed by dilute hydrochloric acid, by Philip Roscoe.

Models of *Megatherium*, *Plesiosaurus*, *Dinoceras*, and *Iguanodon*, by Messrs. Newman and Co., on behalf of the Rev. H. N. Hutchinson.

A series of Flints, containing fossils, by G. E. Dibley.

Photographs illustrative of geological subjects, by E. A. Lardeur.

Sheared and Siliceous Oolitic Limestones, from Ilfracombe, and a series of *Frondiculariæ*, from the Gault of Folkestone, by F. Chapman

Pyromerides from Jersey and elsewhere, and Jersey dykes, by A. M. Davies.

Autograph letters of Cuvier, Owen, J. Hunter, Mary Anning, and others; and some caricatures of the earlier geologists, by C. Davies Sherborn.

ORDINARY MEETING.

FRIDAY, 1ST DECEMBER, 1893.

HORACE B. WOODWARD, F.G.S., President, in the chair.

The donations to the Library, since the last meeting, were read, and thanks were accorded to the several donors.

The following were elected Members of the Association:—Francis R. B. Williams; Percy Emary.

The following papers were read:—

"On a discovery of fossils on a new horizon in the Lower Greensand at Little Stairs Point, Sandown Bay, Isle of Wight," by THOS. LEIGHTON, F.G.S.

"On a specimen of *Eryma elegans* from the Inferior Oolite of Dundry Hill," by HORACE W. MONCKTON, F.G.S.

"The breaking-up of the ice on the St. Mary River, Nova Scotia, and its geological lessons," by G. F. MONCKTON.

"Notes on the Sharks' teeth from British Cretaceous Formations," by A. SMITH WOODWARD, F.L.S., F.G.S.

Specimens were exhibited by Mr. LEIGHTON and Mr. WOODWARD in illustration of their papers.

Mr. DIBLEY showed a paddle of *Ichthyosaurus* from Whitby, with remains of the integument.

ORDINARY MEETING.

FRIDAY, 5TH JANUARY, 1894.

HORACE B WOODWARD, F.G.S., President, in the chair.

The donations to the Library, since the last meeting, were read, and thanks were accorded to the several donors.

The following were elected Members of the Association:—Rev. E. Nelson; Geo. Young; Colonel Underwood; C. A. Born; S. Ackroyd Willmott; N. Alcock.

Mr. CLEMENT REID and Mr. J. D. HARDY were nominated auditors for the ensuing audit.

A paper was read "On the Genesis of the Chalk," by Dr. W. FRASER HUME, F.G.S.

Mr. SALTER exhibited a series of sponges from the Faringdon Gravels.

ON A DISCOVERY OF FOSSILS ON A NEW HORIZON IN THE LOWER GREENSAND, AT LITTLE STAIRS POINT, SANDOWN BAY, ISLE OF WIGHT.

By THOS. LEIGHTON. F.G.S.

[*Read 1st December, 1893.*]

IN October, 1892, it was my good fortune to find that a small fall of the cliff at Little Stairs Point, between Sandown and Shanklin, had brought down a quantity of material from what I take to be Fitton's Bed No. 40 (Group xii) of the Lower Greensand.* No fossils have hitherto been recorded from this group.

The locality is immediately to the south of a small fault, which has the effect of placing the dip nearly horizontal at the point. For this reason, no doubt chiefly, falls of the cliff are of rare occurrence.

I have delayed the publication of these facts for twelve months, on account of the absence of Dr. J. W. Gregory from England, because the fossiliferous horizon contains an interesting Polyzoon bed, the specimens from which I was anxious to submit to him. After this communication was announced, however, Dr. Gregory's happy return has enabled me to include therein the results of his hasty examination of the specimens. The Association is greatly indebted to him for giving his attention to this subject at a time when he is so fully occupied with more urgent matters.

Fitton describes the group of beds in which the fossils were found (*op. cit.*, page 318) as consisting here of "alternate beds of very dark slaty clay and greenish sand," but in his description of the same horizon in Chale Bay he gives further information, and mentions large irregular inclusions "of a coarse sand-rock or conglomerate, marked by rifts of false stratification." An inclusion of that kind is a most accurate description of the rock from which my specimens were obtained, and I can only add to it, that the rock contains (besides the fossils) numerous earthy-iron phosphates.

In the most recent contribution to the geology of the Isle of Wight, the 1889 Memoir of the Geological Survey, Messrs. Reid and Strahan quoted Fitton's identification of this group almost

* *Quart. Journ. Geol. Soc.*, vol. iii (1847), p. 289.

in his own words; it may fairly be taken then that there is no dispute whatever as to the horizon.

Five species were found; of these, two are new to the Isle of Wight, two have previously been recorded from other horizons at Atherfield, whilst the fifth, although not recorded from the island before, appears to be well known in collections, bearing the somewhat indefinite locality "Near Shanklin."

Exogyra conica, Sby., is recorded from Atherfield by both Forbes and Fitton; in the table of the latter (*op. cit.*) it is stated to appear in bed No. 33, and to disappear after bed No. 42. The new horizon is, therefore, within its range as previously recorded. The species was extremely plentiful at Little Stairs Point, occurring in clusters and singly.

Pseudodiadema Fittoni, Wright, is recorded by Dr. Wright in his monograph, published by the Palæontographical Society, from bed No. 4 of Fitton's table at Atherfield, where it is stated to be very rare. I obtained portions of tests of three individuals from a single block at Little Stairs Point, so that it must be fairly common upon this horizon.

? *En'alophora* sp. Dr. Gregory writes me concerning this specimen: "This species is generally identified in England as *Ceriocava ramulosa*, but it seems to me probably an eroded *Entalophora*, but microscopic sections will be necessary to determine its position. The specimen is too much eroded to enable the genus to be determined from it."

Messrs. Reid and Strahan record (*op. cit.*) *Entalophora irregularis*, d'Orb., from the Perna Bed at Atherfield, but I cannot find any record from the island of the name Dr. Gregory rejects, so no doubt this species is new to the island.

Ceriopora micropora, Goldf. This species is new to the Isle of Wight.

Multocrescis, aff. *laxata*, d'Orb. Dr. Gregory writes me concerning this species: "Pergens makes *M. laxata* a synonym of *Heteropora dichotoma*; I suppose d'Orbigny's figure is not to be trusted."

There appears to be no previous record from the island under either of these names, but there is a specimen of this species in the Jermyn Street Museum labelled "allied to Siphodictyon," with the locality "near Shanklin." That specimen looks suspiciously like a rolled pebble. I understand further from Dr. Gregory that there are specimens also in the British Museum, obtained from Mr. Norman, localised "Shanklin," and that one, at least, of them is certainly a rolled pebble. There can be little doubt that all of these come from this horizon, although the locality "Shanklin" has hitherto generally been taken to refer to the highly fossiliferous horizons of Groups XIII and XIV, following above the beds of Little Stairs Point. I have specimens of this species in my cabinet from Atherfield also, and at Jermyn

Street there is one from Hythe; all of the specimens that I have seen (*i.e.*, all except those at the British Museum) are in a similar matrix. This Polyzoon is the most characteristic fossil of the horizon; portions of the rock appear to be entirely permeated by it.

I am indebted to Dr. J. W. Gregory, F.G.S., entirely for the names of the three Polyzoa; and to Mr. E. T. Newton, F.R.S., for assistance with the other identifications.

NOTES ON THE SHARKS' TEETH FROM BRITISH CRETACEOUS FORMATIONS.

BY A. SMITH WOODWARD, F.G.S., of the British Museum (Natural History).

[*Read Friday, 1st December, 1893.*]

THE specific determination of the detached teeth of sharks and skates is little more than guess work; and to decide upon their generic relationships with any approach to certainty is also often very difficult. The teeth vary so much in form and proportions in different parts of the mouth, and some well-defined genera and species differ so little from one another in their dentition, that a scientific nomenclature is sometimes quite impossible. Such teeth, however, are among the commonest fossils in many Cretaceous and Tertiary formations, and it is therefore desirable to attempt to give them provisional names. The result may sometimes express an actual fact—sometimes quite the reverse; but, at any rate, for purposes of correlation it is convenient to have a name for each distinguishable form of tooth. So far as possible, allowance must be made for variation to the extent observed in the jaws of the most nearly related existing genera; and whenever a group of fossil teeth is discovered, evidently belonging to one mouth, the problem of determination is still further simplified.

With this preface, we propose to briefly review our present knowledge of the Selachian teeth met with in British Cretaceous formations, making special reference to those of the still-existing family of Lamnidæ. Such a review, illustrated by the accompanying plates, may prove of value to collectors; while several of the specimens described will add a little of importance to the facts already known. The paper is shortened as much as possible by the omission of references to the literature of the subject, these having been fully given, up to the year 1890, in Woodward and Sherborn's *Catalogue of British Fossil Vertebrata.*

SUB-ORDER TECTOSPONDYLI.

FAMILY *SQUATINIDÆ.*

GENUS Squatina.

The occurrence of extinct "Monk-fishes," or "Angel-fishes," apparently of the still-existing genus *Squatina*, in the English Chalk, was recorded on a former occasion ;* but all of the species except one (*S. Cranei*) are known merely from detached teeth, and are therefore incapable of specific determination. Three characteristic teeth, which will illustrate the brief description previously given, are shown of the natural size in Pl. v, figs. 1-3, all exhibiting the outer aspect : and a lower view of the expanded base of the third specimen is added in fig. 3*a*. The original of fig. 1 was obtained from the Gault of Folkestone, and is probably an anterior tooth ; figs. 2 and 3 represent specimens from the Upper Chalk of Sussex.

FAMILY *MYLIOBATIDÆ* (?).

GENUS Ptychodus.

A general account of the common Upper Cretaceous teeth named *Ptychodus*, with observations on their arrangement in the mouth, was given in the author's earlier paper already quoted ; † and no discoveries of importance have been subsequently made. There are, however, two very rare forms of teeth in the English Cretaceous, to which it may be well to direct special attention ; and collectors would do good service by making known any specimens of this character with which they happen to be acquainted.

1. *Ptychodus Mortoni*, Mantell (Pl. v, fig. 4). This form of tooth is remarkable from the circumstance that the principal ridges of the crown are not transverse, but radiate from a central point. It was first discovered in the Cretaceous of Alabama, where it seems to be a common fossil ; and there is a large, naturally-associated group of teeth of this species, from the Chalk of Kansas, in the Yale University Museum, showing all the various shapes and sizes of teeth met with in a single mouth of the typical species of the genus. The small upper median teeth are not marked with the radiating ridges, but exhibit a minute smooth eminence in the middle of the crown. Most of the English specimens, however, ascribed to *P. Mortoni* in collections, are truly the upper median teeth of other species ; and it is thus of interest to find a single tooth from the Chalk of Winchester which is so characteristic that its close resemblance to the American specimens

* A. S. Woodward, "A Synopsis of the Vertebrate Fossils of the English Chalk," *Proc. Geol. Assoc.*, vol. x (1888), p. 294.

† *Loc. cit.*, pp. 294-298, fig. 1.

cannot be overlooked This fossil, displaying the centre of the crown but not the whole of the border, is shown of the natural size in Pl. v, fig. 4, and is now in the Oxford Museum.

2. *Ptychodus levis*, sp. nov. (Pl. v, figs. 5, 6). Two small teeth in the British Museum from the Lower Chalk and Grey Chalk of Kent differ so much from those of all known species, that we propose to distinguish them by a new name. Though not showing any signs of abrasion, they are remarkably smooth; and the moderately elevated median area of the crown is marked by very feeble transverse ridges and furrows, passing gradually at the extremities into the still more delicate striations of the marginal area, which are chiefly radiating. They most resemble the teeth of *P. decurrens*, but are much more finely ornamented; and the nature of the external layer of the crown is such that it becomes very dark when fossilised. The first specimen (fig. 5) seems to belong either to one of the three median series of the lower dentition or to the innermost paired upper series, and was discovered by Mr. S. J. Hawkins, F.G.S., in the Lower Chalk of Blue Bell Hill, Burham; the second tooth (fig. 6) would occupy a more lateral position in the mouth, and was obtained from the Grey Chalk of Dover.

SUB-ORDER ASTEROSPONDYLI.

FAMILY *NOTIDANIDÆ*.

GENUS Notidanus.

The writer has already sufficiently described the English Cretaceous teeth of *Notidanus*,* and no form differing from the typical *N. microdon* (Pl. v, figs. 7, 8) has been discovered since that description. The new figures of lower teeth here given may prove useful for comparison; and it may be added, in reference to the supposed distinct tooth named *N. pectinatus* by Agassiz, that the discovery of specimens showing much larger anterior serrations than those here indicated, is especially to be desired.

FAMILY *CESTRACIONTIDÆ*.

GENUS Synechodus.

Since 1888, when the generic name *Synechodus* was first proposed for the small Hybodont teeth from the English Chalk,† much new information has been obtained concerning the shark they represent. A complete summary will be found in the British Museum Catalogue of Fossil Fishes. Part I, and in a subsequent paper published in 1892.‡ It will thus suffice on the

* *Loc. cit.*, p. 237.
† *Loc. cit.*, p. 287.
‡ A. S. Woodward, "The Hybodont and Cestraciont Sharks of the Cretaceous Period,' *Proc. Yorks. Geol. and Polyt. Soc.*, vol. xii (1892), p. 62, Pls. i, ii.

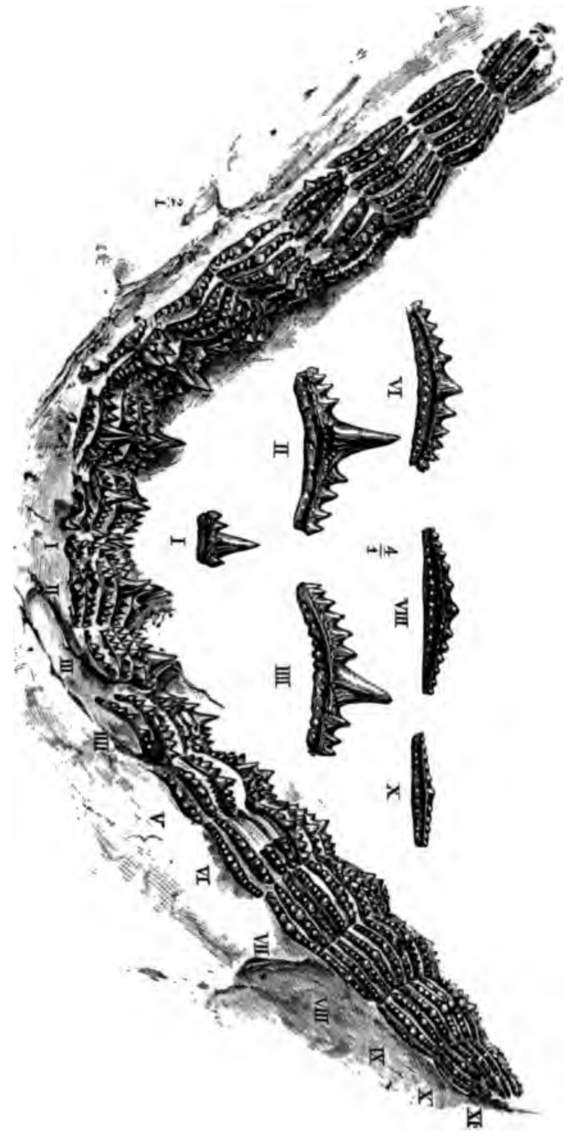


FIG. 1.—DENTITION OF *Synechodus dubrisiensis*, MACKIE SP.; CHALK, SUSSEX.

[*Collection of Henry Willett, Esq., F.G.S., Brighton Museum.*]

present occasion to append a figure of the dentition of the type species, *S. dubrisiensis* (p. 193, fig. 1), for convenience of reference. The teeth themselves cannot be distinguished from those of the well-known Jurassic *Hybodus*; but the fish differs from the latter genus in having well-calcified vertebræ and smooth dorsal fin-spines. The typical *Hybodus*, with notochordal skeleton, cephalic spines, and ribbed fin-spines, is known to occur in the Wealden (*H. basanus*), but has not been detected with certainty in any later deposit.

Genus Acrodus.

The Gault of Folkestone yields typical teeth of this genus, which are remarkably smooth, and hence named *Acrodus levis*. The two type specimens are shown of twice the natural size in the accompanying woodcut (fig. 2), for the loan of which we are indebted to the Editor of the *Geological Magazine*. Only one doubtful tooth has been found in the Chalk, and it is now almost certain that the so-called *Acrodus Illingworthi* is a large *Synechodus*.

Fig. 2.—Teeth of *Acrodus levis*, A. S. Woodw., Gault, Folkestone.

Genus Cestracion.

The Cretaceous shark described on the former occasion* as *Drepanephorus*, proves, on careful comparison, to exhibit no essential differences from the existing Port Jackson Shark, *Cestracion*; and the so-called *D. canaliculatus* and *D. rugosus* have thus been assigned to *Cestracion* in the British Museum Catalogue. The relatively large teeth of the last-named species still seem to be very rare. The latest discovered specimen noticed by the present writer† was obtained by Mr. G. E. Dibley from the Lower Chalk of Warlingham, Surrey.

Genus Gomphodus.

The name of *Gomphodus Agassizi* was given by Reuss to some small teeth from the Cenomanian of Bohemia, much resembling the anterior prehensile teeth of *Cestracion*. Their affinities, however, are still uncertain, and figures of two English specimens are given here (Pl. v, figs. 9, 10) to direct the attention of collectors to them. The original of fig. 9 has much smaller lateral denticles than that of fig. 10, and the first exhibits most rugosity at the base of the crown; both were obtained from the Upper Chalk of Kent.

* *Proc. Geol. Assoc.*, vol. x, pp. 288-290.
† *Proc. Yorks. Geol. and Polyt. Soc.*, vol. xii (1892), p. 67, Pl. ii, fig.

Family *SCYLLIIDÆ.*

Some minute *Odontaspis*-shaped teeth from the English Chalk doubtless belong to small dog-fishes of the family Scylliidæ, and the discovery of skeletons with fins is necessary to determine whether or not the specimens from the Lower Chalk of Kent named *Scyllium antiquum* and *S. dubium* are correctly determined. The only remains described at the time of the writer's last "synopsis" (*loc. cit.*, p. 293) were known as *Scylliodus antiquus*, and it has subsequently been proved that two very distinct fishes were confounded in the original determination. The smaller of these is the fish just mentioned under the name of *Scyllium antiquum*; the larger is the type of the genus *Cantioscyllium.*

Genus **Cantioscyllium.**

The reason why this larger fish can now be distinguished from the smaller is, that by clearing away the matrix the teeth have been exposed. They are shown of twice the natural size in Pl. vi, fig. 1, and are evidently quite distinct from those of *Scyllium.* The dental crown consists of a single elevated principal cone, with one or two pairs of small lateral cones; and the anterior face is produced downwards and forwards mesially, while it exhibits conspicuous striations. Only one specimen is known, the original *Cantioscyllium decipiens*, from the Lower Chalk of Burham, in the British Museum.

Family *LAMNIDÆ.*

The teeth of this family are all solid when completely formed, and those of the principal genera are relatively large, more or less compressed, lanceolate, and pointed, adapted for lacerating.

The Lamnidæ are represented in the English Cretaceous formations by at least four genera, of which two seem to be still living.

Genus **Scapanorhynchus.**

A number of small teeth met with in European Cretaceous formations cannot be distinguished from those of the existing genus *Odontaspis*; and they were originally described under this name by Agassiz. Precisely similar teeth, however, were discovered a few years ago in sharks from the Upper Cretaceous of Mount Lebanon, which are preserved as complete fishes, showing all the fins, and can readily be recognised as quite distinct both from *Odontaspis* and from other living genera. They are named *Scapanorhynchus*, in allusion to their long shovel-shaped snout. Instead, therefore, of retaining the British Cretaceous teeth in the genus *Odontaspis*, it seems more philosophical to refer them to the only known contemporaneous form of shark possessing exactly similar teeth; and we now provisionally recognise three species of *Scapanorhynchus* in the Cretaceous rocks of the S.E. of England. There is some evidence of a fourth species in the Neocomian, but that as yet is unsatisfactory.

1. *Scapanorhynchus rhaphiodon*, Agassiz sp. (Pl. v, figs. 11-13). The teeth of this form are readily distinguished by the sharp and conspicuous striations on the inner (convex) face of the crown. The anterior teeth, of which one is shown from the external aspect in fig. 11, and another from the internal aspect in fig. 12, are destitute of lateral denticles; but all the posterior teeth, as shown in fig. 13, have a single pair of well-developed acuminate denticles. The species ranges from the Upper Greensand to the uppermost Chalk of Norwich.

2. *Scapanorhynchus subulatus*, Agassiz sp. (Pl. v, figs. 14, 15). The reference of this species to *Scapanorhynchus* is more problematical than that of the foregoing; and it is likely that many of the teeth commonly placed here are incorrectly associated with the type of Agassiz. So far as the present writer can judge, the specific name ought to be confined to teeth of the form shown in Pl. v, figs. 14, 15, and such are found in England to range from the Gault to the Upper Chalk. The lateral denticles are large and robust in all the teeth, and the inner face of the crown is always smooth.

3. *Scapanorhynchus gigas*, A. S. Woodw. (Pl. v, figs. 16-18). The present writer has suggested this name for the comparatively large teeth shown in Pl. v, figs. 16-18. They are very slender, often sigmoidally curved, and have sharp edges; the outer face of the crown is flat, except in the anterior teeth, and the inner face is smooth: the crown is somewhat expanded laterally at the base, the sharp edges extending to its inferior limit. Lateral denticles are absent or merely asperities in the anterior teeth, very minute in the others. The species is known only from the Cambridge Greensand.

GENUS Oxyrhina.

The name *Oxyrhina* is given to teeth of Lamnidæ with smooth edges, and destitute of lateral denticles. A shark with similar teeth still exists, and it proves to be scarcely distinguishable from the typical *Lamna*.

Four species have been recorded from English Cretaceous formations, namely, *O. Mantelli*, *crassidens*, *angustidens*, and *macrorhiza*; and of these the teeth of the first two have been well figured.* The third and fourth species have merely been recorded, no figures of British specimens having hitherto been published. The deficiency is therefore now supplied.

* For drawings of a series of teeth of *Oxyrhina Mantelli* from one mouth, see *Catal. Foss. Fishes Brit. Mus.*, pt. i, Pl. xvii, figs. 9-21.

1. *Oxyrhina angustidens*, Reuss (Pl. v, figs. 20-23). These are small teeth known only from the Upper Greensand to the Lower Chalk. They have a very narrow crown with expansion at the base, quite smooth as usual; and in the anterior teeth (fig. 20) the branches of the root are considerably elongated.

2. *Oxyrhina macrorhiza*, Pictet and Campiche (Pl. v, fig. 24). The teeth of this form are very robust and narrow, with the root greatly developed and produced inwards, as well shown in side-view (Pl. v, fig. 24). They appear to be restricted to the Gault and Cambridge Greensand.

GENUS **Lamna.**

A careful review of the fossil teeth named *Otodus* by Agassiz, has convinced most modern authors that the majority must be referred to *Lamna*; at least, that the teeth themselves do not justify their separation from the last-named existing genus. It may be doubted whether the typical *Otodus obliquus* of the Eocene, *Otodus sulcatus* of the Chalk, and the large robust teeth described below as *Lamna semiplicata* are correctly placed here; but in reference to such species as *L. appendiculata* there need be little hesitation. Figures of four of the five British Cretaceous species are now given, with the addition of a French species which will probably be discovered in the Norwich Chalk.

1. *Lamna appendiculata*, Agassiz (Pl. v, fig. 25; Pl. vi, fig. 2). This seems to be the commonest species met with in Cretaceous formations and ranges from the Gault upwards. The teeth are very variable in form, and the accompanying figures give for the first time a precise idea of the limit to which this variation may extend in a single mouth. The fourteen teeth shown in Pl. v, fig. 25, are taken from a naturally-associated group of twenty-five teeth from the Chalk of Maidstone; while the twelve specimens represented in Pl. vi, fig. 2, are from a still larger group of about sixty teeth found associated in the Lower Chalk of Dover. Both groups show the same variation, exactly agreeing with that to be observed in the dentition of a modern *Lamna*; and both are of great interest as exhibiting a diminutive robust tooth (*j*) which corresponds precisely with one of the dwarfed teeth always met with in the recent *Lamna* in the upper jaw immediately beyond the third tooth from the symphysis.

2. *Lamna semiplicata*, Agassiz sp. (Pl. vi, figs. 3, 4). The form of tooth here figured was first recorded from the English Chalk in the writer's previous paper of 1888, and only two specimens are known. The crown is broad and moderately compressed, with a single pair of very broad lateral denticles, sometimes incompletely subdivided; and both faces exhibit vertical wrinkles at the base.

3. *Lamna sulcata*, Geinitz sp. A name given to very large

robust teeth with vertically wrinkled crown and slightly divergent, acuminate lateral denticles. There are specimens in the British Museum from undetermined horizons in the Chalk of Kent, Surrey, and Sussex.

4. *Lamna macrorhiza*, Cope (Pl. vi, figs. 5–9). Numerous teeth of small size of the form shown in the accompanying figures, occur in the English Gault, and they appear to be identical with specimens described by Prof. Cope from the Niobrara Formation of Kansas, U.S.A. They have an elevated narrow crown, wrinkled at the base, with large, very divergent, acuminate lateral denticles.

5. *Lamna arcuata*, sp. nov. (Pl. vi, fig. 10). Two teeth from the Upper Chalk of Norwich appear to represent a new species, of which there is evidence also in the corresponding horizons of Maastricht and Ciply on the continent. A typical specimen is shown from the outer aspect in Pl. vi, fig. 10. The crown is moderately compressed, smooth, acute and narrow, and somewhat bent in the principal hinder teeth; a single pair of large, acuminate lateral denticles is present, and the root is relatively small.

6. *Lamna serra*, A. S. Woodw. (Pl. vi, figs. 11, 12). The teeth thus named, as already mentioned, are merely noticed here in reference to their possible discovery in the Norwich Chalk. They are as yet known only from the Upper Chalk of Mont Aimé, France. The crown is much compressed, elevated, and smooth, with a single pair of broad, acuminate lateral denticles, and one or two smaller outer pairs; the root is short, and the inner nutritive foramen is situated in a groove.

Genus Corax.

Three forms of the familiar serrated teeth known as *Corax* are now recognised in English Cretaceous formations, the first ranging from the Cambridge Greensand upwards, the others confined to the uppermost Chalk.

1. *Corax falcatus*, Agassiz (Pl. vi, figs. 13—15). Though having so wide a range, the largest teeth of this species are found only in the Chalk, and three typical examples are shown in the accompanying figures. The serrations on the margin of the crown in the small (young) teeth are sometimes wanting.

2. *Corax pristodontus*, Agassiz (Pl. vi, figs. 16—18). The teeth thus named are of a comparatively large size, and scarcely distinguishable from *C. falcatus*, except in the greater relative width of the crown and the usually more convex form of its anterior margin. Only one naturally-associated set of teeth has hitherto been discovered, and that in the Upper Senonian or Danian of Ciply, Belgium.*

* A. S. Woodward, "The Fish-fauna of the Danian of Ciply." *Geol. Mag.* [3], vol. viii (1891), p. 112, Pl. iii, figs. 10—16.

3. *Corax affinis*, Agassiz (Pl. vi, figs. 19—22). The third species of *Corax* was confounded with *C. falcatus* by the present writer in 1888, but the series of figures now given will serve to render its distinction simple. The crown is slender, smooth or very feebly serrated, notched prominently at the base of the hinder margin, and less so upon the anterior margin, thus producing a broad posterior denticle and a less distinct anterior denticle. The only known English specimens were obtained from the uppermost Chalk of Norwich.

FAMILY **Carchariidæ.**

In conclusion, it may be added that no teeth of Carchariidæ have hitherto been discovered in the English Cretaceous, and, notwithstanding several records on the continent, it is still very uncertain whether there is any evidence of their existence in Cretaceous times. Most of the teeth are indistinguishable from those of Lamnidæ in external form, but they may be known by possessing an internal cavity even when fully developed. Any peculiar serrated teeth that may be met with are especially worthy of examination in reference to the latter point; for it can hardly be supposed that *Carcharias* and its allies are an exclusively Tertiary group.

EXPLANATION OF PLATES.

PLATE V.

FIG. 1.—*Squatina* sp.; tooth, outer aspect.—Gault; Folkestone. (B. M., No. 47120.)

FIG. 2.—*Squatina* sp.; tooth, outer aspect.—U. Chalk; Brighton. (B. M., No. 25768.)

FIG. 3.—*Squatina* sp.; tooth, outer and inferior (3*a*) aspect.—U. Chalk; Lewes. (B. M., No. P. 5322.)

FIG. 4—*Ptychodus Mortoni*, Mantell; tooth, portion of upper aspect.—Chalk; Winchester. (Oxford University Museum.)

FIG. 5—*Ptychodus levis*, sp. nov.; tooth, upper aspect.—L. Chalk; Blue-bell Hill, Burham. (B. M., No. P. 6524.)

FIG. 6.—Ditto; ditto.—Grey Chalk; Dover. (B. M., No. P. 51.)

FIG. 7.—*Notidanus microdon*, Agass.; tooth, outer aspect.—Chalk; Sussex. (B. M., No. 25793.)

FIG. 8.—Ditto; tooth, inner aspect.—U. Chalk; Norwich. (B. M., No. 24927.)

FIG. 9.—*Gomphodus* sp.; tooth, outer and inner (9*a*) aspects.—Chalk; Gravesend. (B. M., No. 41702.)

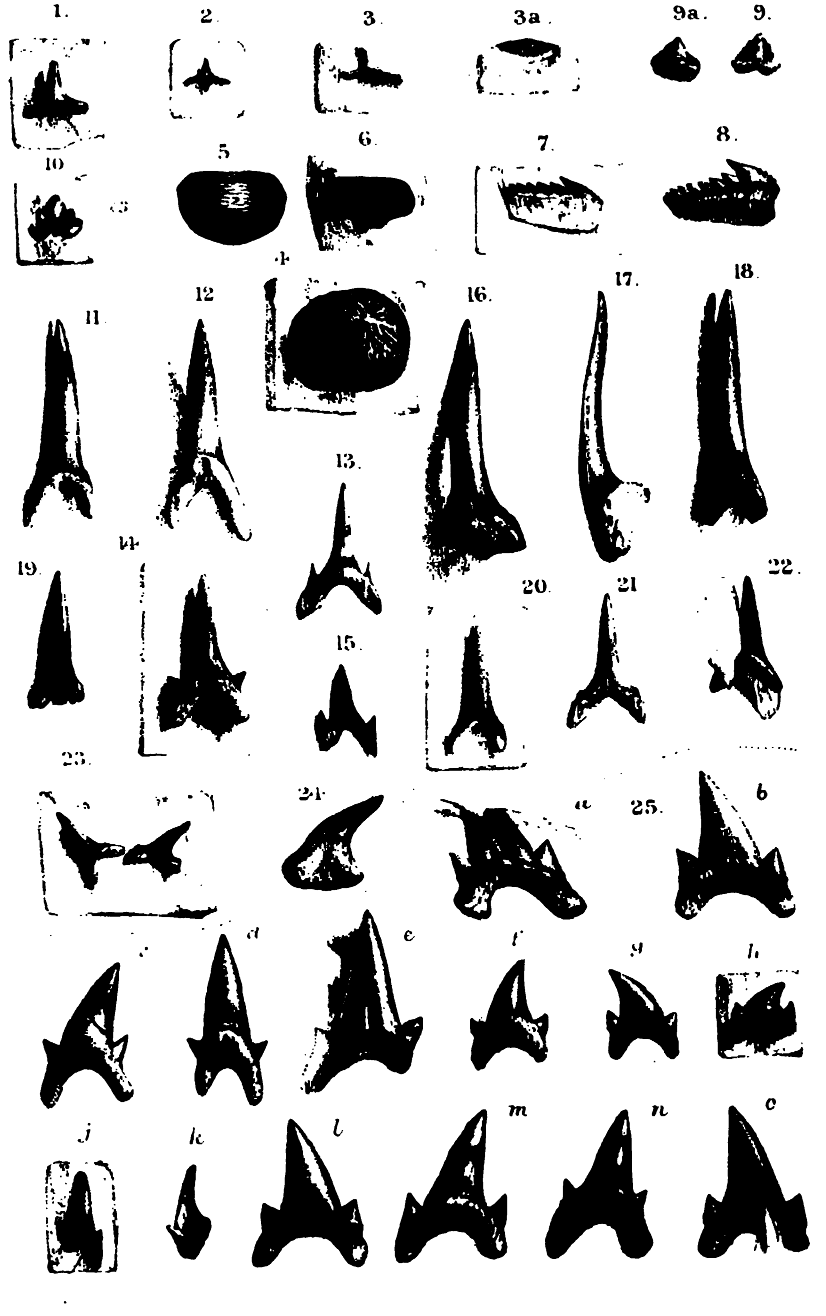
FIG. 10.—*Gomphodus* sp.; tooth, outer aspect, thrice natural size.—Chalk; Charing, Kent. (B. M., No. P. 334.)

FIGS. 11, 12.—*Scapanorhynchus rhaphiodon*, Agass. sp.; two anterior teeth, outer (11) and inner (12) aspects.—Chalk; Kent. (B. M., Nos. P. 404, 43080.)
FIG. 13.—Ditto; posterior tooth, inner aspect.—U. Chalk; Shalford, near Guildford. (B. M, No. 49952.)
FIG. 14.—*Scapanorhynchus* (?) *subulatus*, Agass. sp.; anterior tooth, outer aspect.—Chalk; Halling, Kent. (B. M., No. 41707.)
FIG. 15.—Ditto; posterior tooth, outer aspect.—Chalk; Arundel. (B. M., No. 49949.)
FIGS. 16-18.—*Scapanorhynchus* (?) *gigas*, A. S. Woodw.; three anterior teeth, outer (16), lateral (17), and inner (18) aspects.—Cambridge Greensand; Cambridge. (B. M., No. 46362.)
FIG. 19.—*Oxyrhina angustidens*, Reuss (?); tooth, outer aspect.—Cambridge Greensand; Cambridge. (B. M., No. 46362.)
FIG. 20.—Ditto; anterior tooth, outer aspect.—Chalk; Halling. (B. M., No. 41707*b*.)
FIG. 21.—Ditto; tooth, outer aspect.—L. Chalk; Blue-bell Hill, Burham. (B. M., No. P. 6522.)
FIG. 22.—Ditto; tooth in matrix, inner aspect.—Chalk; Cherry Hinton, Cambridgeshire. (B. M., No. P. 2381.)
FIG. 23.—Ditto; two teeth in matrix, outer aspect.—Chalk; Glynde, near Lewes. (B. M., No. 49948.)
FIG. 24.—*Oxyrhina macrorhiza*, Pict. & Camp.; tooth, lateral aspect.—Cambridge Greensand; Cambridge. (B. M., No. 35128.)
FIG. 25, *a*—*o*.—*Lamna appendiculata*, Agass.; fourteen associated teeth.—Chalk; Maidstone. (B. M., No. 39053.)

PLATE VI.

FIG. 1.—*Cantioscyllium decipiens*, A. S. Woodw.; four associated teeth; three (*a*, *b*) from outer aspect, one (*c*) seen from below, twice natural size. L. Chalk; Burham. (B. M., No. P. 5890.)
FIG. 2, *a*—*m*.—*Lamna appendiculata*, Agass.; twelve associated teeth.—L. Chalk; Dover. (B. M., No. P. 45.)
FIG. 3.—*Lamna semiplicata*, Agass. sp; imperfect tooth, outer aspect.—L. Chalk; Rochester. (B. M, No. 43514.)
FIG. 4.—Ditto; tooth in matrix, from outer and inner (4*a*) aspects.—L. Chalk; Charing, Kent. (B. M., No. P. 327.)
FIGS. 5—9.—*Lamna macrorhiza*, Cope; teeth in matrix, all outer aspect except fig. 7.—Gault; Folkestone. (B. M., Nos. 47218*b*, P. 12*a*, *b*.)
FIG. 10.—*Lamna arcuata*, sp. nov.; tooth, outer aspect.—U. Chalk; Norwich. (B. M., No. 48956 *b*.)
FIGS. 11, 12.—*Lamna serra*, A. S. Woodw.; two teeth, outer (11) and inner (12) aspects.—U. Chalk; Mont Aimé, Marne, France. (B. M., No. P. 5761.)
FIGS. 13, 14.—*Corax falcatus*, Agass.; two teeth, outer (13) and inner (14) aspects.—Chalk; Kent. (B. M., No P. 2333.)
FIG. 15.—Ditto; tooth, outer aspect.—Chalk; Bromley. (B. M., No. 25766.)
FIGS. 16—18.—*Corax pristodontus*, Agass.: three teeth, outer aspect.—U. Chalk; Norwich. (B. M., No. 48946.)
FIGS. 19—22.—*Corax affinis*, Agass.; four teeth, outer (19, 22) and inner (20, 21) aspect.—U. Chalk; Norwich. (B. M., Nos. 35650, 48947.)

*** Unless otherwise stated, the figures are of the natural size. B. M.= British Museum, and the numbers refer to the register of the Geological Department.



F. H Michael del. et lith.

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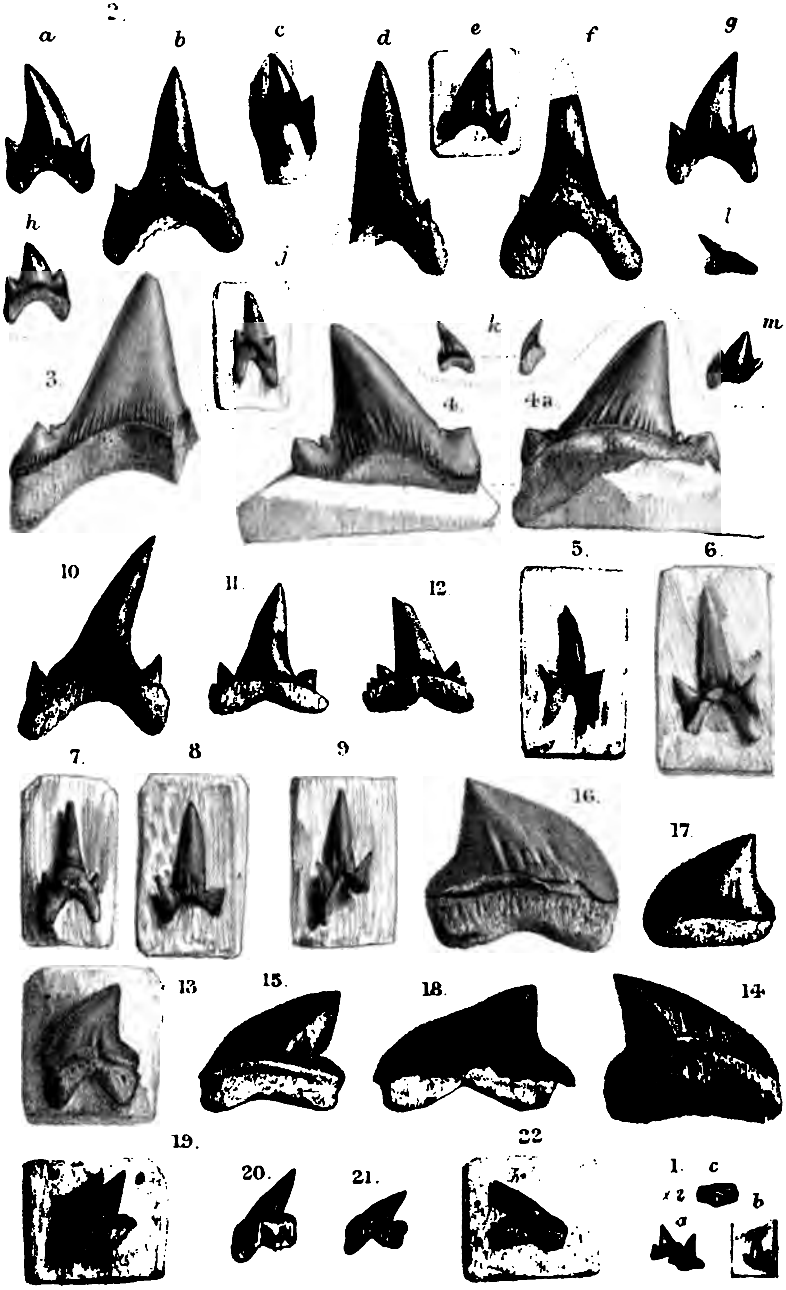
CRETACEOUS SELACHIAN TEETH.



F. H. Michael del et lith.

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CRETACEOUS SELACHIAN TEETH.

ANNUAL GENERAL MEETING.

FEBRUARY 2ND, 1894.

HORACE B. WOODWARD, F.G.S., President, in the Chair.

Messrs. L. Belinfante and A. Hogan were appointed Scrutineers of the ballot.

The following Report of the Council for the year 1893 was then read:—

THE numerical strength of the Association on the 31st of December, 1893, was as follows:—

Honorary Members	15
Ordinary Members—	
a. Life Members (Compounded)	156
b. Old Country Members (5s. Annual Subscription)	8
c. Other Members (10s. Annual Subscription) .	356
Total . . .	535

This increase of fourteen Members on the previous return is the more encouraging as the Council have felt it necessary to enforce the removal clause embodied in Rule XI.

During the year fifty-one new Members were elected. The Council regrets that the Association has lost five Members by death:—James W. Davis, H. R. Hind, Rev. Andrew Johnson, Henry Lainson, and T. Adams Phillips. Mr. James W. Davis, though not a contributor to our publications, will be always remembered by our Members for his researches on fossil fishes, and to his own townsmen for his energetic efforts for the promotion of scientific and general education. Mr. T. Adams Phillips was one of our original Members, joining the Association on its foundation in 1858; while among those who have passed away, the name of Edward Charlesworth will recall to many an old and familiar figure at our meetings and excursions.

During the past year the receipts (omitting £2 for surplus books and £11 3s. for the "Record" and "Paris Basin") have amounted to £275 14s. 10d., a larger sum than has been received in any year since the extremely prosperous years 1886 and 1887. Of this amount your Council has handed over to the Trustees for investment £63, as representing Life Compositions, and a portion of the amount obtained by sale of publications. The expenditure of the year has amounted to £227 1s. 11d., leaving a balance of £5 11s. 2d. to be carried on to the current

GEOLOGISTS' ASSOCIATION.

Dr. Income and Expenditure for the Year ending Dec. 31st, 1893. Cr.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance in hand on Jan. 1st, 1893	6	15	3	By Printing "Proceedings"	86	8	10
„ Life Compositions	42	0	0	„ „ Monthly Circulars	19	17	3
„ Admission Fees	24	0	0	„ Illustrations	24	6	0
„ Annual Subscriptions	174	14	11	„ Miscellaneous Printing	7	13	6
„ Dividend on Nottingham Corporation Stock ...	22	2	9	„ Postages	37	3	9
„ Advertisements	1	9	0	„ Addressing	6	15	9
„ Sale of Publications	11	8	2	„ Library	10	5	8
„ Sale of Old Books	2	0	0	„ Attendance, Gas, etc., at Evening Meetings ...	18	4	0
„ Sale of "Record"	9	6	9	„ Excursions	9	16	6
„ Sale of "Paris Basin"	1	16	3	„ Insurance	1	1	0
				„ Stationery	4	14	2
				„ Miscellaneous Expenses	0	15	6
				„ Purchase of Nottingham Corporation Stock ...	63	0	0
				„ Cash in hand, Dec. 31st, 1893	5	11	2
	£295	13	1		£295	13	1

The foregoing Accounts of the Treasurer of the Geologists' Association have been examined and found correct.

The amount of Stock held by the Geologists' Association on the 23rd January, 1894, is vouched by the Chief Accountant of the Bank of England as £797 17s. 3d.

January 9th, 1894.

CLEMENT REID,
JAS. D. HARDY. } *Auditors.*

year. The Trustees now hold £797 17s. 3d. Nottingham Corporation Stock in trust for the Association, and at present prices this is equivalent to £5 4s. 7d. per head for each of the 156 Compounders living. Under these circumstances your Council consider the financial position of the Association extremely satisfactory. It has, nevertheless, been felt for some time that the proportion of Members compounding was increasing with undue rapidity, and as this was obviously owing to the very low composition fee (£5 5s.), it was decided that a proposal to increase it to £7 10s., or fifteen years' purchase (the rate adopted by many other societies), should be laid before the Association; and a special general meeting was held on July 7th, at which the proposal was considered and agreed to. Advantage was taken of the opportunity to make a number of alterations, mostly of small importance, in the rules of the Association. Copies of the new rules have been forwarded to every Member, and as the alterations were fully discussed at the special general meeting, it may suffice here to mention that, according to them, newly-elected Members are not entitled to any privileges of membership until their admission fee and first annual contribution have been paid; and that when a Member's subscription is twelve months in arrear, he also ceases to be entitled to the rights or privileges of membership. Your Council is happy to be able to report that the number of Members whose subscription is in arrears is not large.

During the year the usual five numbers of "Proceedings" have been issued, only one of them being behind date. As compared with the previous years, these numbers show a slight diminution in total bulk, as they consist of 184 pages; on the other hand there is an increase in the number of illustrations, which consist of four plates and thirty-seven figures.

Many valuable donations have been received into your library, among which may be specially mentioned, Clement Reid's *Memoir on the Pliocene Deposits of Britain*; Reid and Strahan's *Memoirs on the Geology of the Isle of Wight*, and Fox Strangway's and Horace Woodward's three *Memoirs on the Jurassic Rocks of Britain*, presented by the Director General of the Geological Survey.

In accordance with the long-expressed wishes of the Members your Council has undertaken the difficult and laborious task of reorganising the Library. This necessitated an overhauling of the entire collection of books, and a rearrangement of them in some more convenient form than heretofore. The Council, acting under Rule XVII., felt it advisable to sell certain books of little or no value to the Association.

You will learn with regret that the weak state of health consequent on a long and serious illness compelled Mr. Bradford to resign his post last November. Acting under Rule XIV., the Council at once nominated a successor, and while your thanks are due to Mr.

Bradford for the nine years spent in Library work, they are also due to Mr. W. J. Atkinson, who has entered upon his hard duties (assisted by Mr. Litchfield and Mr. Fleck) with a vigour that augurs well for the Members. You will be gratified to hear that the Librarian has been empowered to bind many serials that have hitherto been inaccessible to Members; and that he has been further permitted to issue to Members loose pamphlets, or parts of a serial publication at his own discretion. A revised list of books in the Library has also been ordered to be printed.

The following is a list of the Papers read at the evening meetings:—

"On the Bases of the Classification of Ammonites," by the Rev. Prof. J. F. BLAKE, M.A., F G.S.

"The Sandgate Landslip," by W. TOPLEY, F.R.S.

"Glacial Sands at Highgate Archway," by W. J. LEWIS ABBOTT, F.G.S.

"Consideration of the principal Phenomena connected with Volcanoes," by J. W. L. THUDICHUM, M.D.

"The Geology of Dublin and its Neighbourhood," by Professor W. JOHNSON SOLLAS. F.R.S.

"On a discovery of Fossils at Little Stairs Point, Sandown Bay," by THOS. LEIGHTON, F.G.S.

"On an *Eryma* found at Dundry," by H. W. MONCKTON, F.G.S.

"The breaking-up of the Ice on the St Mary River, Nova Scotia, and its Geological Lessons," by G. F. MONCKTON.

"On the Sharks' Teeth from British Cretaceous Deposits," by A. SMITH WOODWARD, F.L.S., F.Z.S.

Lectures were delivered by the Rev. H. N. Hutchinson, "An Attempt to restore some Extinct Animals" (Jan. 6th); by George Barrow, F.G.S., "The Highland Schists and their Metamorphism" (Mar. 3rd); and by E. T. Newton, F.R.S., "The Reptiles of the Elgin Sandstones" (May 5th); all these lectures were illustrated by the lantern.

Your thanks are due to these lecturers.

A Conversazione was held on November 3rd.

Your Council have observed with considerable satisfaction the increase in the number of exhibits at the evening meetings, and they would suggest to exhibitors that a more favourable opportunity would be afforded to Members to inspect the exhibits if they were arranged and labelled a short while before the commencement of ordinary business, the time being necessarily short at the conclusion of the meeting.

The general attendance at the meetings is also most satisfactory, an average of sixty being maintained, while on occasions when a specially interesting general paper or lecture is delivered, no less than 200 persons have been present to reap instruction and to gratify the lecturer.

The following Museums, etc., were visited during 1893:—

British Museum (Natural History), on March 18th, when Mr. W. Carruthers, F.R.S. (Keeper of the Botanical Department), gave a demonstration on "Gymnosperms from the Devonian to the present time."

The Norfolk and Norwich Museum, on March 30th, when the collections were explained by the Curator, Mr. James Reeve, and Mr. J. T. Hotblack.

On March 31st a visit was paid to Norwich Castle, which is shortly to receive the Museum collections, and the plans were explained by Mr. T. Southwell, F.Z.S.

The Collection of Flint Implements from the Farnham Gravels, formed chiefly by Mr. H. A. Mangles, F.G.S., on May 13th, when the specimens were explained by Mr. Mangles and his friends.

The Bath Museum, on May 23rd, under the guidance of the Rev. H. H. Winwood.

The Collection of Flint Implements from the neighbourhood of Ightham, Kent, formed by Mr. B. Harrison, on June 24th, when the specimens were explained by Mr. Harrison.

The Library, Geological, Zoological, and Anatomical Museums, Anatomical and Chemical Laboratories, and other buildings at Trinity College, Dublin, on July 25th, under the guidance of Prof. W. J. Sollas, F.R.S.

The Science and Art Museum, Dublin, on July 30th, when the Director of the Museum, Dr. Valentine Ball, C.B., F.R.S., received the party, and gave demonstrations in the various departments. A pamphlet, descriptive of the contents of the Museum of special interest to geologists, was prepared and printed by Dr. Ball for the use of Members of this Association.

The following is a list of the excursions made during the past year, detailed reports of which will be found in numbers 3 and 5 of vol. xiii of the "Proceedings":—

DATE.	PLACE.	DIRECTORS.
March 25th.	Ilford.	F. C. J. Spurrell, F.G.S.
March 31st to April 4th (Easter).	Norwich, the Bure Valley, Cromer, and Lowestoft.	The President, J. H. Blake, F.G.S., and Clement Reid, F.L.S., F.G.S.
April 15th.	Dartford Heath.	F. C. J. Spurrell, F.G.S.
April 22nd (whole day).	Brill.	Prof. J. F. Blake, F.G.S.
May 6th.	Amwell and Ware.	Joseph Francis, M.Inst. C.E., and W. Topley, F.R.S.
May 13th (whole day).	Farnham.	H. A. Mangles, F.G.S, and H. W. Monckton, F.G.S.
May 20th to 23rd (Whitsuntide).	Bath, Dundry, Bradford-on-Avon and Westbury (Wilts).	The President, W. H. Wickes, E. Wilson, F.G.S., and Rev. H. H. Winwood, M.A., F.G.S.
June 3rd.	Dorking.	Prof. G. S. Boulger, F.L.S., F.G.S., and T. Leighton, F.G.S.
June 10th (whole day).	Sandgate and Folkestone.	T. Leighton, F.G.S., and F. G. Hilton Price, F.S.A., F.G.S.
June 17th.	Blackheath and Bexley Heath Railway.	T. V. Holmes, F.G.S.

DATE.	PLACE.	DIRECTORS.
June 24th.	Sevenoaks.	W. J. Lewis Abbott, F.G.S., and E. T. Newton, F.R.S.
July 8th.	Abinger.	T. Leighton, F.G.S.
July 24th to 30th (long excursion).	Dublin and Wicklow.	Prof. Grenville A. J. Cole, F.G.S., and Prof. W. J. Sollas, D.Sc., F.R.S., F.G.S.
August 12th.	The Deneholes of Hangman's Wood.	T. V. Holmes, F.G.S.

Steady interest has been shown during the past year in the excursions of the Association, and the high standard of former years has been well maintained. Probably no more interesting meeting than the Long Excursion has been held since the foundation of the Association. Scientifically and socially it was a pronounced success. The welcome accorded the Association by Ireland, as represented by her men of science and her Daily Press, upon this first visit to the sister island, was hearty and sincere. Amongst the many gentlemen mentioned below, to whom your thanks are due, you are particularly indebted to Prof. Cole, who, as local secretary, contributed so considerably to the success of the meeting; as well as to Prof. Sollas, the senior director of the excursion.

Your thanks are due to the directors of all the excursions; also to the following ladies and gentlemen for assistance and hospitality:—

Mr. W. Carruthers, F.R.S., on March 18th; Mr. F. W. Harmer, F.G.S., Mr. James Mottram, and Mr. Thomas Southwell, F.Z.S., at Norwich; Mr. H. A. Mangles, F.G.S., and Miss Mangles, at Tongham, and Mrs. Anderson, of Waverley Abbey, on May 13th; Mr. H. W. Garrett, at Midford, Bath; Mr. J. R. Tennear, at Westbury (Wilts); Mr. W. Rigby, on June 17th; Mr. B. Harrison, on June 24th; Prof. Val. Ball, C.B., LL.D., F.R.S., Rev. Maxwell H. Close, F.G.S., Mrs. and Miss Dunne, Rev. S. Haughton, D.D., F.R.S., Mr. G. H. Kinahan, Prof. and Mrs. Jas. Lyon, Rev. Father Murphy, S.J., Prof. J. P. O'Reilly, Mrs. Sollas, Dr. R. Lloyd Woolcombe, LL.D., and Mr. A. B. Wynne, F.G.S., during the Long Excursion; and Mr. W. Cole and Capt. Whitmore, on August 12th.

In consequence of the reconstruction of the old meeting room, the Council of University College has arranged that we shall hold our meetings in the New Mathematical Theatre, with the privilege of occasional use of the Botanical Theatre should a specially large attendance be expected for any particular lecture. By the kind consideration of Mr. J. M. Horsburgh, the Secretary of the College, arrangements have been made by which our library is stored in room No. 53, next door to the usual meeting room. This unexpected and convenient concession has considerably assisted the efforts of your Council to render the library more available to Members. Your thanks are especially due to the Council of University College, and to Mr. Horsburgh, for the increased conveniences now offered, as well as for the permission accorded to us to hold our conversazione in their Library.

The changes in our House List, as shown on the balloting papers now in your hands, are considerable, and unexpected. Mr. Horace B. Woodward, your President, feels himself unable by reason of his official duties to hold your chair for a longer period than one year. When the author of *The Geology of England and Wales* consented to become your President, a deep satisfaction was felt by all and every member, and while your thanks are due to Mr. Woodward for the care and attention he has paid to your welfare, you will share the regrets of the Council that he is unable to hold office for the usual period of two years.

Mr. R. S. Herries, your Treasurer, having been to New Zealand, your Council accepted the temporary services of Mr. Horace W. Monckton. Mr. Herries will resume his duties on his return, and your thanks are due to him more especially for the care bestowed on the revision of your bye-laws; and to Mr. Monckton for so promptly and satisfactorily filling the gap caused by Mr. Herries' sudden departure. Your thanks are also due to the following members of your Council who retire on this occasion:—Mr. T. V. Holmes; Mr. F. A. Bather; Mr. James Fox; Mr. John Hopkinson; Mr. C. Johnson; Mr. J. Slade; Mr. W. Topley. Your Council feel that they cannot let pass this opportunity of recalling to your memory that Mr. Hopkinson has served the Geologists' Association in one capacity or other for twenty-nine years.

Your Council have pleasure in recommending for election as honorary member:

CHARLES LAPWORTH, whose discoveries in the Highlands of Scotland and in other parts of Britain have been of such signal service to Geology. It will be remembered that it was before this Association (vol. viii (1884), pp. 438—442), that Professor Lapworth read one of his historic papers, and tabulated those convictions relating to Scottish Geology, which have finally been acknowledged to be correct.

The names of those suggested by your Council to fill the vacant offices will be found on the balloting papers.

On the motion of Dr. G. J. Hinde, F.G.S., seconded by General McMahon, F.G.S., the Report was adopted as the Annual Report of the Association.

The Scrutineers reported that the following were duly elected as Officers and Council for the ensuing year:

PRESIDENT:

Lieut.-Gen. C. A. McMahon, F.G.S.

VICE-PRESIDENTS:

Rev. Prof. J. F. Blake, M.A.
W. H. Hudleston, M.A., F.R.S.
Miss C. A. Raisin, B.Sc.
Horace B. Woodward, F.G.S.

TREASURER:

R. S. Herries, F.G.S., 53, Warwick Square, S.W.

COUNCIL:

John Bradford, F.G.S.
H. Hutchins French, F.G.S.
W. Bolger Gibbs, F.R.A.S.
J. Walter Gregory, D.Sc., F.G.S.
Horace W. Monckton, F.G.S.
E. T. Newton, F.G.S.
George Potter, F.R.M.S.
F. W. Rudler, F.G.S.
W. W. Watts, M.A., F.G.S.
B. B. Woodward, F.G.S., F.R.M.S.
A. Smith Woodward, F.G.S.
A. C. Young.

SECRETARIES:

C. Davies Sherborn, F.G.S., F.Z.S., 540, King's Road, Chelsea, S.W.
Thomas Leighton, F.G.S., Lindisfarne, St. Julian's Farm Road, West Norwood, S.E.

EDITOR:

A. Morley Davies, F.G.S., 28, Haldon Road, West Hill, Wandsworth, S.W.

LIBRARIAN:

Wheatley J. Atkinson, F.G.S., 76, Christchurch Road, Streatham Hill, S.W.

On the motion of Mr. L. Belinfante, seconded by Mr. G. Potter, the thanks of the Association were unanimously voted to the Officers and Members of Council retiring from office, to the Auditors, and to the Scrutineers.

The President then delivered his address, entitled "Geology in the Field and in the Study."

On the motion of Mr. Osborne White, seconded by Dr. Fraser Hume, it was unanimously resolved that the President's address should be printed *in extenso*.

This terminated the Annual Meeting.

ORDINARY MEETING.

FRIDAY, 2ND FEBRUARY, 1894.

Lieut.-Gen. C A. McMAHON, F.G.S., in the chair.

The donations to the Library, since the last meeting, were read, and thanks were accorded to the several donors.

There being no paper, the meeting then terminated.

ORDINARY MEETING.

FRIDAY, 2ND MARCH, 1894.

Lieut-Gen. C. A. McMAHON, F.G.S. in the chair.

The donations to the library, since the last meeting, were read, and thanks were accorded to the several donors.

Leonard James Spencer was elected a Member of the Association.

A letter was read from Professor Lapworth, thanking the Association for electing him an Honorary Member.

The following papers were read :—

"The Hythe Beds of the Lower Greensand, in the Liphook and Hind Head District," by BINSTEAD FOWLER.

"Tertiary Man," by J. B. M. FINDLAY.

Mr. ALFORD exhibited some rich specimens of gold-bearing quartz from Mashonaland.

ORDINARY MEETING.

FRIDAY, 6TH APRIL, 1894.

Lieut.-Gen. C. A. McMAHON, F.G.S., in the chair.

The donations to the library, since the last meeting, were read, and thanks were accorded to the several donors.

Messrs. W. Golding, Captain Stiffe, T. R. Croger, and A. J. Maslem were elected Members of the Association.

Dr. G. J. HINDE, F.G.S., delivered a lecture on "Fossil Sponges: Their Characters, Modes of Occurrence, and Conditions of Preservation."

The lecture was fully illustrated by specimens and diagrams both by Dr. HINDE and Dr. HENRY WOODWARD.

ON A SPECIMEN OF ERYMA ELEGANS FROM THE INFERIOR OOLITE OF DUNDRY HILL.

By HORACE W. MONCKTON, F.L.S., F.G.S.

[*Read 1st December*, 1893].

THE discovery of this fossil crustacean when the Association visited Dundry Hill last May has already been recorded in the report of the excursion (*ante*, p. 131). I found it on a large heap of stone in the quarry on the Chew Stoke road near the Butchers' Arms. The appearance of the stone in which the fossil is preserved led those present to believe that it came from one of the upper beds in the quarry, probably from the zone of *Ammonites Parkinsoni*, that is, from above the ironstone of the *A. Sauzei* zone, from which so many fossils were obtained on the occasion.

The specimen exhibits the left side of the carapace of *Eryma elegans*, Opp.* The furrows on the cephalothorax dividing the branchial, cardiac, and gastric regions are particularly well shown, but the exceptional feature in the specimen is the beautifully clear marking of the punctuation on the outermost layer of the carapace over nearly the whole of the specimen.

By the kindness of Mr. James Carter, of Cambridge, I was enabled to exhibit at the conversazione in November last a very similar specimen from the Great Oolite limestone of Northampton. On it, however, only a small portion of the outermost layer of the carapace is preserved, and over the greater part the subjacent granulated layer is exposed.

Mr. Carter remarks that considerable differences of character in specimens of this species result both from age and from the degree of perfection in which the several layers of the test are preserved. He also tells us that he possesses a plaster cast of a specimen from Longwy, Moselle (zone of *A. Parkinsoni*), which agrees with the British form. In the Proceedings of the Cotteswold Naturalists' Field Club, vol. viii (1881—2) p. 56, a specimen of *Eryma* from the middle coral reef of Leckhampton is figured and described by Dr. T. Wright under the name of *E. Guisei*, but Mr. Carter tells me there can be but little, if any, doubt that the form described is identical with *E. elegans*, Opp.

My thanks are due not only to Mr. James Carter but also to Dr. Henry Woodward and to Mr. H. B. Woodward for assistance in the compilation of this note.

* Oppel, *Palæontologische Mittheilungen*, 1862, p. 26 and Tab. 4, fig. 7.

THE GENESIS OF THE CHALK

By W. FRASER HUME, A.R.S.M., D.Sc., F.G.S.

[*Read 5th January*, 1894.]

THE average traveller or pleasure-seeker, who visits our south-eastern counties, cannot fail to be struck with the beauty and grandeur of the chalk cliffs which bound our shores, yet he seldom detects in their apparently homogeneous mass any change of detail or variation of structure. The geologist, however, probes deeper; yet in the earlier stages he, too, merely judged by the superficial characteristics of the exposures known to him, and basing himself on flints or other external lithological peculiarities, divided his strata into

Chalk with many flints,
Chalk with few flints,
Chalk Marl,
Upper Greensand.

This division, as is well known, has now completely broken down, for even in England have we not a "Chalk with flints," without flints, so close at home as Margate? Is there not a "Chalk with few flints," almost composed of huge tabular flints in Yorkshire? Chalk Marl and Upper Greensand, too, are terms which cease to have any significance as soon as we get beyond the district best known to us. This is so fully recognised to-day, that the terms Upper, Middle, and Lower Chalk have been almost universally accepted by English geologists for the first three divisions mentioned above, though Upper Greensand remains of well-marked, but somewhat anomalous definition.

It must be understood, however, that any nomenclature based on lithological characters, becomes valueless to students engaged in international correlation, and I can only urge, that it would be well to impress, even on students of our local geology, the advisability of being acquainted with D'Orbigny's terms of Senonian, Turonian, and Cenomanian applied to Upper, Middle, and Lower Chalk respectively. These possess the advantage of being based on the Latin names for races now extinct, and as such can be used in any part of the world for Upper Cretaceous deposits, without reference to their lithological composition.

In 1862 Hébert went further, and showed the possibility of subdividing the great divisions into minor zones, receiving their names from some prominent fossil, apparently more or less limited to its own particular band. These have been extended to our country by our distinguished fellow-member, Dr. C. Barrois, whilst Messrs. Jukes Browne and Whitaker have shown us that two definite nodular breaks, the Melbourn Rock and Chalk Rock, serve as marked features commencing and closing the Middle Chalk epoch.

Let us remember that we are dealing with a vast lapse of time, and that if we wish to have the histories of the successive changes which proceeded during this period, our divisions must be as numerous, sharp, and distinct as possible. I shall presently discuss its history on these lines, and will meanwhile place before you the following zone classification as being the one which will be adopted in this paper.

SENONIAN (Upper Chalk) . .	13. *Belemnitella mucronata.*
	12. *Marsupites.*
	11. *Micraster cor-anguinum.*
	10. *Micraster cor-testudinarium.*
TURONIAN (Middle Chalk) . .	9. Chalk Rock (*Holaster planus*).
	8. *Terebratulina gracilis.*
	7. *Inoceramus labiatus* or *Rhynchonella Cuvieri*
CENOMANIAN (Lower Chalk) . .	6. *Belemnitella plena.*
	5. *Ammonites Rhotomagensis.*
	4. *Holaster subglobosus.*
	3. *Am. varians* or *Rhynchonella Martini.*
	2. *Plocoscyphia mæandrina.*
Do. (Upper Greensand) .	1. Chloritic Marl (*Pecten asper*). *

We may approach our subject from two different points of view: a General, which treats of the question at issue by a comprehensive examination of the whole of its relations and extent; and a Local, which grasps the details of a particular region, and then attempts to apply the principles thus obtained to the unravelling of the whole.

In general, then, what is the extent of the area in Europe over which, at one time or another during the Upper Cretaceous period, chalk, or some deposit having immediate relationships with it, was laid down? As from its western outcrop in Antrim to its eastern exposure at Uralsk in East Russia is 2,000 miles, and from its northern boundaries in Sweden and Scotland, to its final appearance in the South of France, near Nice, is not less than 500 miles, it may fairly be presumed that the Chalk Ocean in Europe covered an area of over 500,000 sq. miles. (This is exclusive of any similar deposits in Asia, and ignores the chalk observed in the United States, as in the neighbourhood of Kansas City.)

At the present time, it is possible to divide this great region into three minor divisions:

A. The *Anglo-Parisian* Basin, which has been very carefully studied, both by English and French geologists.

B. The *Germanic* Basin, comprising a most important series of zonal divisions in Westphalia, and some very remarkable shore-deposits in Saxony and Bohemia.

*For a further discussion of subdivisions see Jukes-Browne, *Geol. Mag.* (1880), p. 248, and Prof. Morris, *Proc. Geol. Assoc.*, vol. viii, p. 208. See also an important discussion in Prestwich's *Geology* vol. ii, chap. xx.

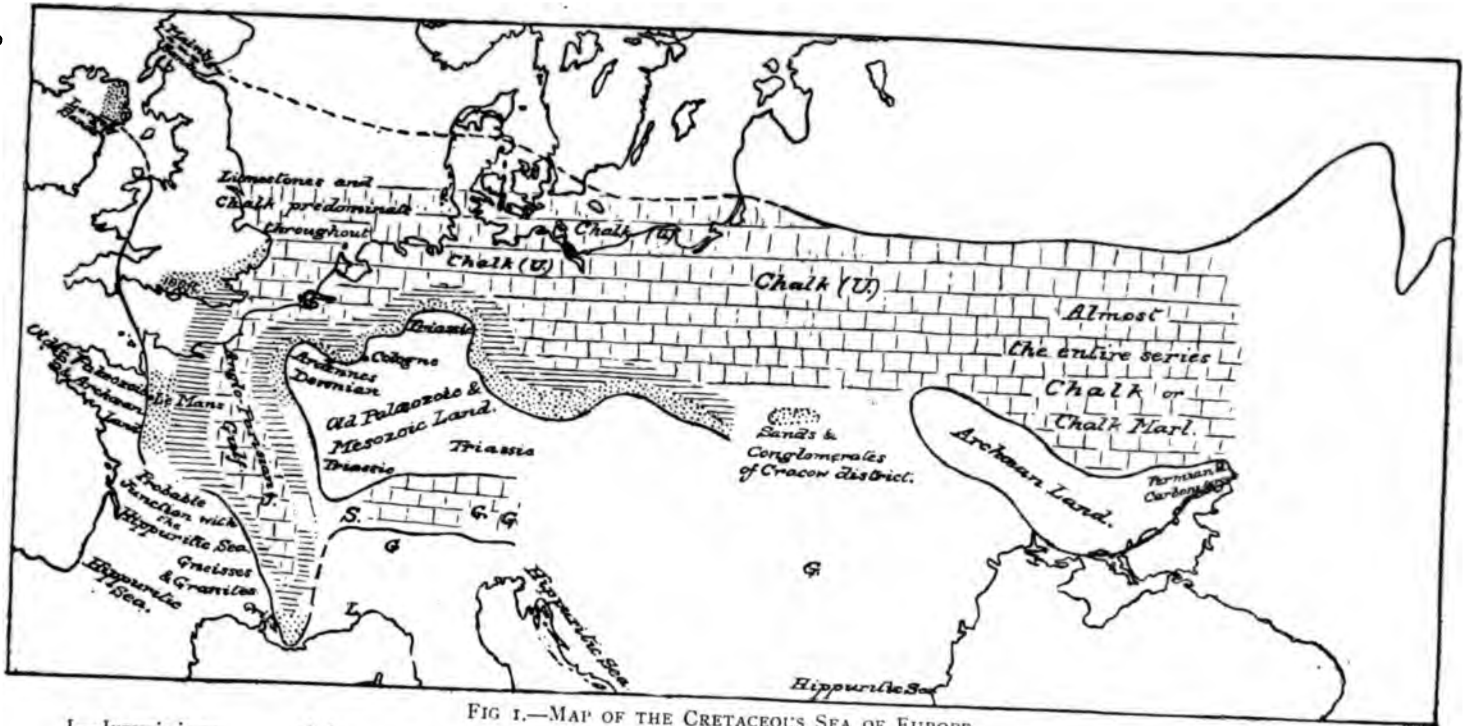


FIG 1.—MAP OF THE CRETACEOUS SEA OF EUROPE.

J.—Jurassic is now exposed, but in all probability the Cretaceous formerly covered this area. L.—Flysch of Ligurian Apennines, considered as Cretaceous by Sacco. S.—Red Limestone of Pays d'Enhaut, referred to Cretaceous by Schardt. G.—Gosau coral Limestones. *Chalk (U)* indicates that the Upper Chalk alone is exposed, otherwise most of the details on the map are those which probably existed during Cenomanian times.

C. The *Russian* Basin, which occupies an exceptional position, owing to the apparent absence of marked division planes. In other respects, *viz.*, extent and depth of deposit, this appears to occupy the premier position, but palæontologically its characters are less varied, and surface deposits render its study far more difficult than in the previous cases.

A bird's eye view of the Upper Cretaceous as a whole reveals the striking fact, that with some remarkable exceptions, the Chalk volume closes at the same period, and that over the whole of its vast area *Belemnitella mucronata* is found to be the highest zone fossil from Ireland to Savoy, and from Scotland to Orenburg. Only here and there are there traces of strata bridging over the gap between the Cretaceous and the Tertiary. It is therefore with special interest that the student turns to the few torn and fragmentary pages which carry on the broken and tangled sequence of Cretaceous history.

As these will not be useful in our main argument, I will only briefly examine them here.

The *Danian* beds, as they have been termed, fall readily into three divisions:

A. Strata having Cretaceous affinities, but containing Gasteropod genera common in the London Clay. They are also largely characterised by the presence of Bryozoa.

B. Strata rich in Tertiary Gasteropoda, of types subsequently found in the Calcaire Grossier of Paris. Only a few Cretaceous forms link these with the former. They are frequently pisolitic in structure.

C. Limestones characterised by Lamellibranchs only.

A and *B* are more commonly yellow limestones, and most of these relics appear to be unconformable to the chalk beneath.

A. In Belgium, at Maestricht, is the familiar yellow limestone characterised by the presence of Gasteropoda (*Voluta*, *Fasciolaria*, etc.), and large Echinoderms of the *Hemipneustes* type, together with Foraminifera (*Calcarina* and *Tinoporus*) attaining large proportions. Mosasauria and Bryozoa are also noticeable.

At Ciply, in the same country, is a yellow limestone with Bryozoa, *Hemipneustes*, and Foraminifera.

In France, in the north of the department of the Manche, is also a limestone which has been preserved by means of a fault. This contains *Baculites anceps*, *Mosasaurus Camperi*, and many Bryozoa, and is immediately overlain by Eocene limestone.

Finally, on Faxoë Island, in Denmark, Gasteropoda of the London Clay type are again prevalent, but in addition Bryozoa and corals are present in great abundance. Some of the deposits here, and on the opposite coast of Sweden, have been evidently formed near a shore, attaining the character of conglomerates and sandstones, though the inter-relationships of the various rocks are, from the want of continuous exposures, difficult to determine.

B. The type of this series is the well-known Calcaire pisolitique of the neighbourhood of Paris, which is sharply marked by the presence of such typical Tertiary forms as *Cerithium*, *Crassatella*, and *Cardium*. Indeed, *Nautilus danicus* (met with in the Faxoë strata) is the only link binding it to the Bryozoan Limestones.

In a boring at Mons, in Belgium, beneath the Eocene sands, a friable yellow limestone was met with containing *Quinqueloculina* and calcareous Algæ, together with Cretaceous Echinids, yet at the same time rich in a marine Gasteropod fauna, and such freshwater types as *Pupa*, *Physa*, *Auricula*, etc.

A particularly interesting case is that presented at some localities in the Lublin Government of Poland, *e.g.*, Frampol and Voichekova, where there is a direct association of the two divisions made familiar by the western types. Here a Pisolitic Limestone directly overlies one containing Bryozoa, but further details as to their faunal contents I have not been able to obtain. In the latter *Multicavea magnifica* is the most characteristic fossil.

C. The Danian beds in E. Europe and Asia are marked by an abundance of Lamellibranchs of the Oyster types. The yellow limestone with *Ostrea decussata*, which builds up the historic heights of Inkerman, is referred here. This rock is largely used as a building stone in Odessa and the other towns of the Crimea.

Mention may also be made of a large series of marls with *Gryphæa*, *Ostrea*, and *Exogyra*, occurring in Turkestan, and referred by Romanoff to the Danian, under the name of the Ferghana formation.

It may be mentioned that the nearest approach we have to a Danian deposit, viz., at Trimingham, near Cromer, contains bands of *Ostrea lunata*, with simple corals; whilst Prof. T. R. Jones informed Dr. Barrois that he knew of a quarry in Norfolk full of *Baculites*, which may be referred to this horizon.

Let us now briefly trace the probable shore-lines of the Cretaceous Sea.

All three members of the United Kingdom possess evidences of the near presence of a coast-line.

The extreme shore condition is met with in Scotland, where only the uppermost zone, that of *Belemnitella mucronata*, is true chalk 10ft. thick, the remainder being represented by sandstones with a seam of coal, and at the base glauconitic sands, with *Pecten asper* and *Exogyra conica.**

In the north of Ireland the Upper Chalk is, in the main, calcareous, but the Hibernian Greensands (which appear to include the zones of the Middle and Lower Chalk) are very coarse-grained, and Dr. Barrois has pointed out that even in the upper zones

* Judd, J. W., *Quart. Journ. Geol. Soc.*, vol. xxxiv, p. 729

traces of the near presence of land may be detected. Among these he specially notes the hardened nodular bands, the bedded arrangements of the fossils, and the variability in zonal thickness from one point to another. These, together with the marked transgressive overlap to the south, and the general reduction in zonal thickness all point in the same direction. Dr. Barrois thinks that the coast-line may have been formed by the Silurian ridge of County Down.*

The third area is that of Devonshire, but as this will be more fully dealt with further on, I need only remind you here of the marked overlap to the west, and the change of the Gault clay to a sandy condition in the same direction. Crossing over to France, we find the Archæan rocks of Brittany bearing no trace of the invasion of the Cretaceous sea.

But positive evidence of land in this direction is overwhelming. Passing southward from Rouen, the Cenomanian beds become less and less calcareous, until they at length pass into the sandy condition at Le Mans, in Sarthe. The sands and grits here are over 300 ft. thick, and at their base contain numerous plant remains, including a *Magnolia*, and also the well-known bivalve, *Trigonia*, still abundant in tropical seas.

It may also be mentioned that *Pecten asper* occurs in glauconitic sands at the base, but farther north is present throughout the greater part of the Cenomanian series, in beds of micaceous and glauconitic chalk.

The strata of Turonian and Senonian age show similarly traces of the near proximity of land, the chalk being either sandy, micaceous, or passing into a true marl.

In the South of France, similar conditions are met with. Thus near Orange, in Vaucluse, over 225 ft. of grits occur, containing several species of *Trigonia*. As is well known, the Hippuritic Limestone occupies the S. of France, but the Anglo-Parisian Gulf appears to have run parallel to the eastern border of France, almost as far south as Nice. A short distance from the latter town occur marly limestones with *Micraster cor-anguinum* and other Cretaceous fossils.

If the Cenomanian exposures be followed from the Marne district eastward, the strata are found more and more to lose their littoral character. Thus, at Sancerre, 140 miles from Le Mans, sands have completely disappeared, marls and micaceous chalk taking their place. Finally, in Aube, deep-sea conditions are predominant, the succession from below being (1) Chalky marl with oysters, (2) Marly chalk with Cephalopods, (3) Massive chalk with Echinids. This appears to be the deepest centre of the gulf in this part of France, for on passing N.E. towards the Ardennes and Belgian region, the conditions become reversed. Thus, at St. Menehould, in the north of Marne, the Cephalopod marly

* Barrois, C., *Recherches Terr. Cret. Angl. et Irlande* (Lille, 1876), p. 217.

chalk is replaced by glauconitic and pure sands containing *Pecten asper.*

Finally in the N.E. of France and South Belgium the conditions are decidedly littoral. Not only are the Cenomanian beds (often known as Tourtia), coarse conglomerates with pebbles of grits and other rocks, but the Turonian and Senonian strata become very marly, containing up to 70 per cent. of clayey material. This is more especially true for the former division. The Belgian Upper Chalk is throughout of a littoral character, this condition culminating in the well known sands of Aix-la-Chapelle. (The Ardennes region is well known, thanks to the brilliant work carried out by the French geologists, notably] M. Gosselet, Dr Barrois, and latterly by investigations made on the microscopic structure of the chalk, these being worked out by M. Cayeux. Fortunately their records of this shore-line are preserved in the journals of the Société Géologique du Nord.)

But hitherto the evidence of continental land has been insignificant compared with that met with in Germany. The shore-condition is most marked in Saxony and Bohemia. The Cenomanian here is represented by a coarse sandstone, at the base, as at Niederschöna, containing evidence of a luxurious dicotyledonous vegetation.* The Turonian is more generally of a marly nature, but in the Upper Senonian the sandstone (Quadersandstein) is developed on a magnificent scale, giving rise to the splendid scenery of Saxon Switzerland.

Not only so, but further evidence of the shore-condition is afforded by the Mollusca present in the German strata. Thus, out of 66 genera, 35 occur together in European areas at the present time at a depth of less than 36 fathoms, and the greater part of the remainder are tropical forms which are normally living within the above shallow area. Among these the student will be surprised to find such forms as *Voluta*, *Conus*, and *Strombus*, not merely as occurring in the uppermost parts of the series, but as actually living in the German area during the whole of Cretaceous time, so that the Danian instead of presenting absolutely new conditions, merely marks the continuation of a Gasteropod fauna which had been long ago established on the shore-lines of Bohemia, the Hartz, Silesia, Westphalia, and Galicia.†

Furthermore, there is here evidence of the great elevations closing the Cretaceous period, for a Quadersandstein with *Pecten quadricostatus* and *Lima multicostata* was found by Dr. Müller in 1848, to overlie the marls of the Upper Chalk near Aix-la-Chapelle, and further a Quadersandstein with *Belemnitella mucronata* is found *above* white chalk at Vaels.

Becks also noted the existence of Greensand alternating with

* De Saporta, *Le Monde des plantes* (1879), p. 134.

† Geinitz, *Kreide Gebirge in Deutschland* (tables at end); and Römer's works.

marls, at both Senonian, Turonian, and Cenomanian levels,* whilst the predominance of materials derived from the shore-line is well seen on examining Schlüter's zonal succession.†

It is therefore clear that the old Central European continental surface, or Hercynian fold, has had an enormous effect on the German Upper Cretaceous at large. The marly condition of the upper zones is met with even so far away as the Lublin Government of Poland.

Corresponding to the great German continental elevation is a region of maximum depression. Overlying younger and younger rocks passing southward, and scarcely even known to pass north of the 55° latitude line, the chalk of South Russia is a formation possessing a homogeneity not observed in more western regions.

It is here that we can alone hope to discover the characters of the more central portions of the Cretaceous sea, for every-where else in Europe the continuity is broken by the existence of marine areas, the strata beneath whose waters we can scarcely hope ever to be able to study.

In Russia, a vast coating of loess, and Tertiary deposits renders investigation most difficult, but fortunately borings, some of which have been made in the most central parts of the southern plains, have thrown considerable light on the lithological succession in these regions.

Messrs. Winning, who have carried out some of the most important borings in South Russia, kindly placed the whole of their records at my disposal, the results from the study of which will be found in the *Geol. Mag.* for Sept., 1892.

Throughout there appears to be no trace of the presence of nodular bands, but in the great boring at Kharkov, where the chalk was no less than 1,831 feet thick, three divisions are plainly discernible. These are briefly:—

		Feet.
A.	Pure white Chalk (without flints)	297
B.	White Chalk (slightly less pure than above)	670
C.	More clayey Chalk	134
D.	Blue Chalk Marl	101
E.	Chalk Marl (alternately darker and lighter)	156
F.	Grey Chalk (whiter and softer below)	312
G.	White Chalk (soft below)	161
		1,831

Greensand here begins as a green sandy clay. To the south, all the lower white Chalk (G) contains moderate-sized nodules of flints, whilst in a boring at Soumy a hard chalk with dark flints succeeds the Chalk Marl, but the Upper Chalk is quite free from these concretions.

The indications are therefore in favour of a period of

* Geinitz, *loc. cit.*, p. 17.
† See De Lapparent, *Traité de Géologie*, 1st ed., p. 1096.

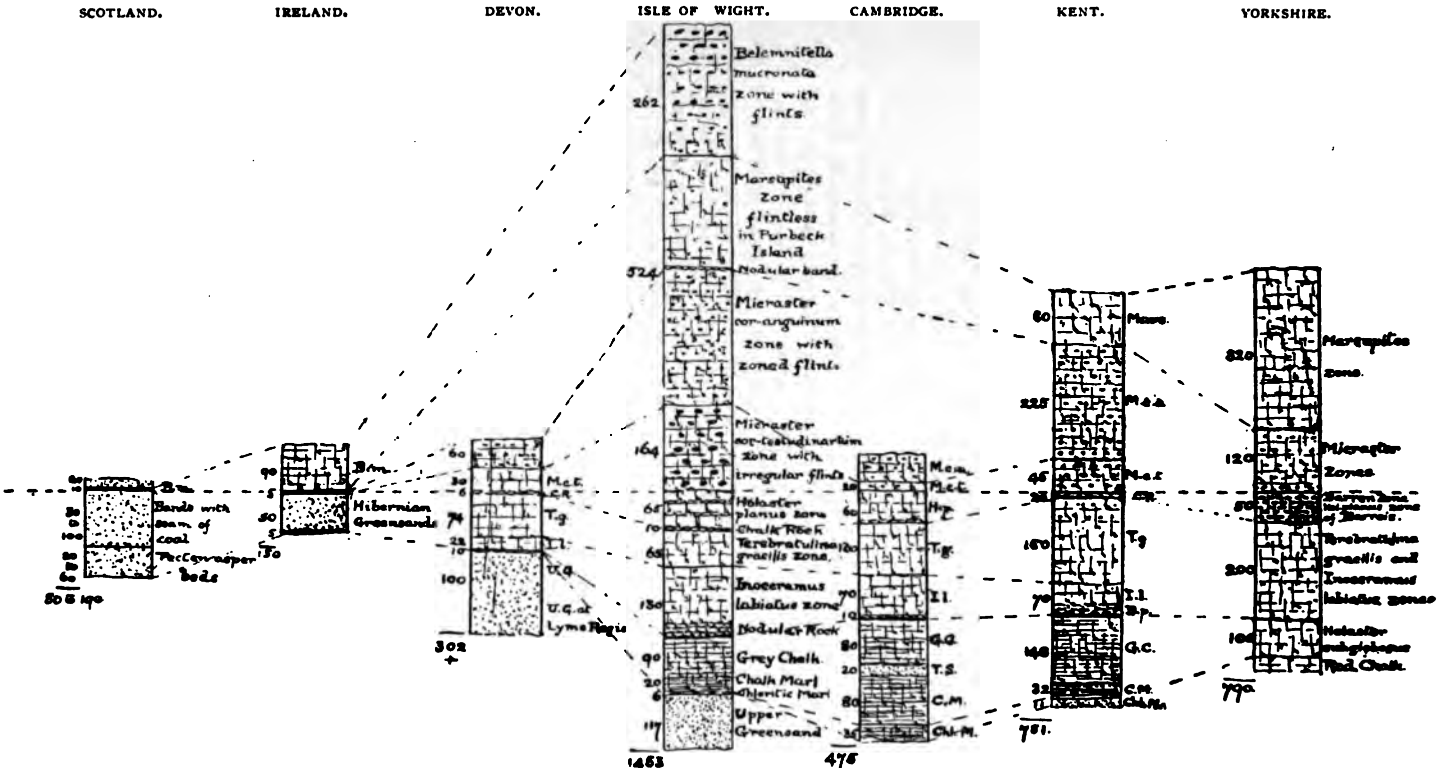


FIG. 2.—SECTIONS REPRESENTING THE VARIATIONS IN THICKNESS OF THE UPPER CRETACEOUS ZONES FOR SOME OF THE PRINCIPAL LOCALITIES IN THE BRITISH ISLES.

Abbreviations of zonal names :—

R.m.—*Belemnitella mucronata*. M.c.t.—*Micraster cor-testudinarium*. B.p.—*Belemnitella plena*. C.M.—Chalk Marl.

depression, preceding a slight elevation, this again being succeeded by a long-continued season of depression. The conditions thus appear to be the exact opposite of those occurring in the German area at the same epoch.

Russian geologists have found it impossible to separate the Upper Cretaceous into zones, the preserved fauna being of a mixed Senonian and Turonian type, with predominance of genera more common in the former. *Belemnitella mucronata* appears to be of constant occurrence throughout all this vast lapse of time.

After leaving Russia, the northern boundary of the Cretaceous Ocean westward is not easy to trace, though the presence of the Ahus sandstone and conglomerates in the S. of Sweden indicate shore conditions in that direction.

Having now briefly considered the coast-lines of the Cretaceous Ocean, and the general distribution of the Chalk, and structures related to it by palæontological characters, I will invite your attention to a consideration of the history of the successive zones of the Upper Cretaceous in our S.E. counties, the views here set forth being based partly on work in the field, partly on laboratory study, and partly on reading and comparison with recent deep-sea research.

What effect will land areas bordering the Cretaceous Sea have on the character of the deposits laid down therein? It will, I think, be generally conceded that those zones which consist of detrital materials will thin seaward, whilst those of deeper sea origin, more rich in calcareous components, will thin landward. In other words, if the varying thicknesses of the zones be represented by a wedge or cone, the apex of the wedge will point seaward in the case of beds derived from a land surface, and landward in that of deep sea strata.

It has long been suggested that in Devonshire or to the S.W. of that area some old land surface existed in Cretaceous times. Thus we all know the transgressive overlap of the Upper Cretaceous beds over the older rocks in the West. Again, the Gault, which is a thick dark clay in Sussex, passes to the condition of a sandy clay in the Isle of Wight, and finally becomes in its upper part in Devonshire indistinguishable from the Upper Greensand strata overlying it.

Upper Greensand.

But it is more especially the marked formation of the Upper Greensand which I propose to take as my example of a zone composed of materials derived from the land, and which can at the same time be shown to be thinning away from the old coast-line. After consulting the works of several of the leading authorities on our subject, I feel led to the conclusion that we can in general divide our Greensand into four main divisions:—

1. Greensand over 100 ft. thick. This holds good for the county of Dorset, South Wilts, and the Isle of Wight, with the maximum thickness (180 ft.) at Lyme Regis. I only know of one exception, viz., at Punfield Cove, near Swanage, Purbeck Island, where it is only 60 ft. thick.

2. Greensand 60–80 ft. thick. The region will be found to have a very definite parallelism with the former, and includes the Haldon Hills in Devonshire, N. Wilts, most of Berks, part of Oxfordshire, and Hampshire.

3. Greensand 20–50 ft. thick. This belt of equal thickening comprises Berkshire, Surrey, and Sussex.

4. The Greensand dies away altogether at Tring, in Hertford, and thins rapidly in Kent, being only 18 inches thick at Aylesford, and absent both at Rochester and Dover. It is thus evident, on a first glance, that there does appear to be such a gradual thinning in a zone formed under the conditions described above, and that the sandy materials have been carried over a distance of 150 miles from the parent source.

So far all is well, but now come startling exceptions, one of the most striking occurring in our own neighbourhood. At Crossness, near Erith, the Greensand suddenly thickens to 65 ft. Does this case stand alone? May it not be correlated with the existence of a 20 ft. Greensand at Harwich, and the 7 ft. thickness of the same deposit at Norwich. May it not be that we are here dealing with the line of a great current flowing northward, and that the apparent exception really contains in itself evidence of a most interesting character?

In the second place, this gradual transition is to some extent accompanied by an actual change in the lithological condition of the Greensand itself. Take, for instance, the *Pecten asper* zone, which represents here its upper part. Roughly speaking, there are variations corresponding to each of the divisions previously laid down.

In Dorset, the Isle of Wight, and S. Wilts, bands of chert (shown by Dr. Hinde to be largely composed of siliceous sponge-spicules) play an important *rôle* in the upper part of the series, and frequently form a most striking feature, as in the picturesque scenery of the Undercliff.

The coarse sandy condition without signs of chert is prevalent in our Division No. 2, as for example at Petersfield and Alton in Hants, and near Devizes in N. Wilts. Sandy marls and clays, and fine siliceous malms, or firestones, occupy the great part of Division No. 3, as in Buckingham, Surrey, and Kent, whilst similar conditions are found at Wissant, on the opposite coast of France. Southward, too, calcareous constituents increase, producing a friable calcareous sand-rock, as at Eastbourne.

Faunally, the evidence points already to the commencement of a great depression. I can only just touch upon this subject, as it will still require much careful thought and comparison. The main suggestions here brought forward are based on deductions derived from a study of the Mollusca. I have availed myself (as regards the Cretaceous forms) of the carefully prepared index of Upper Cretaceous Fossils of England and Ireland, published by Mr. E. Westlake, F.G.S. This gives a tabular summary of the fossils obtained by Dr. Barrois whilst studying our own islands in 1875-76. The Geological Survey Memoirs have also been laid under contribution, and as far as possible, a study of the Natural History Museum specimens has been carried out. For the nature of present deep-sea distribution, reference has been especially made to the *Challenger* Report: Lamellibranchiata, and to Fischer's *Manuel de Conchyliologie*. From these comparisons it is probable that the Blackdown Beds were laid down within the 30 fathom line.

On studying the Upper Greensand, it is soon noticeable that the fauna, compared with the above, is distinctly altering. The zoophagous Gasteropoda (so abundant in Germany, and moderately common at Blackdown) have practically disappeared, and already the great Monomyarian division of the Lamellibranchs takes up a leading position. The percentage relations are as follows:—

Monomyaria, 49 per cent.; Dimyaria, 30 per cent.; Gasteropoda, 15 per cent..

The fauna is of a character similar to that now met with between 30 and 150 fathoms. The nearest approach to the former condition occurs only in the west, as at Lulworth, in Dorset. The *Pecten asper* zone outside our Division 1, has no trace of the shallow-water forms obtained at Lulworth, and Pourtalès in 1850 dredged, from a depth of 150 fathoms, a sand composed of *Globigerinæ* and black sand (probably greensand, according to Murray and Renard). I have been struck with the frequent mention of greensand at the above depth in the *Challenger* reports. This deposit is said to be not frequent within the 100 fathom line, and to extend to about 900 fathoms. Consequently, taking the faunal and lithological characters together, 150 fathoms may be considered as the average figure for the deposition of the Upper Greensand.

Chloritic Marl.

If, then, the Greensand current passed more to the east, we can understand that it must necessarily have been the Chloritic Marl Sea which eroded the Gault at Cambridge, the *Pecten asper* zone being simply a coast-line deposit in that sea. We all admit depression during the Gault period, followed by elevation. As far as my present study has gone, I am inclined to think that the *Ammonites inflatus* zone, the lower part of the Upper Greensand, represents the rise. At the maximum elevation, *Pecten asper*, which seems to be a typical coast-line form, was able to extend its range (probably from France, where it was present throughout the greater part of the Cenomanian period), and finding suitable conditions in our area, developed well while these lasted. As soon as depression was well advanced, this form was cut off from its principal littoral centre, and thus died out soon after the close of the Upper Greensand conditions. Indeed, it never seems to have spread very far to the east beyond our division No. 1.

Mr. M. W. Norman has discussed* the sequence of these lower beds. A glance at Plate X in his article will convince the reader of the importance of the change of fauna, even though the discussion be restricted to the Ventnor neighbourhood. At the base are Trigonias and a large number of other Dimyarian bivalves, commonly present within the 30 fathom limit. After the first 30 ft. these rapidly diminish, until finally in the chert beds Pectens, Ammonites, and Brachiopods assume almost absolute sway.

If, then, the Chloritic Marl represents the product of the action of the advancing and eroding sea, the presence of so many derived fossils in it is explained. The Upper Greensand would represent the temporary triumph of an off-land current over the advancing denuding agent. Messrs. Murray and Renard† state that there is a great tendency to the formation of phosphatic nodules where currents meet: consequently, as depression continued, the nodular band would be constantly advancing westward as the shore-line retreated. We should not be surprised, therefore, to find that the Chloritic Marl of the W. of England should show signs of having been laid down at different periods of Cenomanian time, and that in Somerset it should contain forms of so high a zonal character as *Holaster subglobosus*, *Ammonites Rhotomagensis*, and *Amm. Mantelli.*‡

It may be stated that the Chloritic Marl of Dorset contained over 50 per cent. of $CaCO_3$, thus exceeding the percentage amount obtained from a modern greensand dredged in 98 fathoms. We may therefore reasonably conclude, if this be combined with the Molluscan evidence, that the base of the Cenomanian, even in the West, was laid down on a sea-bottom 100 fathoms at least below the ocean surface. Thus, before starting the Chalk proper at all, the limit assigned by Dr. Gwyn-Jeffreys§ has already been passed.

If, then, the Upper Greensand be a current deposit, must it be considered as littoral or deep-sea? This involves a discussion

* *Geol. Mag.* (1882), p. 440.
† *Challenger* Reports: Deep Sea Deposits, p. 396.
‡ Woodward, *Quart. Journ. Geol. Soc.*, vol. xxxiii, pp. 446, 447.
§ *Brit. Assoc. Report*, 1877.

of definitions. What is meant by a deep-sea or littoral deposit? Fuchs, Forbes, and others have maintained that the littoral zone extends to a depth of about 50 fathoms, the coral region forming the base line, whilst beyond this limit the deposits must be regarded as of deep-sea origin. On the other hand, Dr. Günther proposes to extend the junction-line to 500–600 fathoms. I venture to say here, that the main body of our chalk shows but few traces of extreme littoral deposition, and, at the same time, that we have no present evidence of any cretaceous strata laid down under purely abyssal conditions. In the present paper I shall pursue the following classification :—

a. Littoral Deposits, agreeing with the conditions laid down by Fuchs, etc., and characterised by the presence of large Algæ, and by the preponderance of carnivorous Gasteropods. The coral zone acts as a transition-line between this and our next division.

Minor sub-divisions, such as Intertidal, Laminarian, Coralline, etc., may also be recognised.

b. Coast-line Deposits, containing over 5 per cent. of materials evidently derived from the shores of the continental areas (terrigenous), comprising sands, clays, and marls, frequently rich in glauconitic contents, and characterised by an abundant fauna, in which certain Echinoderms (*e.g.*, *Holaster*), Ammonites and Lamellibranchs are specially abundant. In the shallow parts Dimyarian bivalves are well marked, but Monomyarian forms obtain the preeminence in the deeper sea region. Arenaceous Foraminifera and other non-pelagic organisms form a good proportion of the finer organic materials.

c. Deep-sea Deposits (Benthal Zone of Gwyn-Jeffreys), in which the detrital materials do not exceed 5 per cent., and which are therefore almost pure limestones, the fauna at the same time showing a marked increase in Crinoids and Echinoids like *Ananchytes* (*Echinocorys*) and *Galerites* (*Echinoconus*). Pelagic Foraminifera, together with Coccoliths and Rhabdoliths, also abound.

d. Abyssal Deposits, having a lack of calcareous material, and being almost devoid of organic life.

The Greensand and Chloritic Marl undoubtedly occupy a high position in the scale of coast-line deposits, and the former, especially in our Division 1, probably becomes a true littoral formation. Thus no less than 21 species of corals have been described from the Haldons, in Devon, by Prof. Martin Duncan. Also in the Isle of Wight fragments of wood and Chelonian remains have been noticed by Mantell and Parkinson, and the former are very apparent in the greensand near Lulworth. On the other hand, Echinodermata are rare, and Brachiopoda not abundant, whilst Dimyarian Molluscs are very common in the lower strata. All these facts point to littoral conditions in the

Isle of Wight, though the presence of a rich Brachiopod and Echinoderm fauna at Warminster, in Wilts, may show more favourable depth conditions to have existed in that quarter.

Chalk Marl and Grey Chalk.

Having now considered the Upper Greensand, as in the main a distinct coast-line deposit, part of which was laid down during elevation after the Gault depression, and part during the commencement of the second, or great Upper Cretaceous depression, and having regarded the Chloritic Marl as a deposit containing fragments of material derived by renewed marine denudation from the re-elevated land, we must now turn to a consideration of the strata which form the great mass of our Lower Chalk, and are distinguished mainly by their marly character. In the first place, the Lower Chalk, which invariably appears to have a predominance of calcareous materials in its composition, undoubtedly thins in those directions where the existence of land would most probably be inferred. Thus it is 198 feet thick at Dover, 126 to 187 feet in the Midlands, 116 feet in the Isle of Wight, and only 100 feet in Devon, at the same time being partially sandy in the latter county. It is, in the main, impossible to consider each zone separately, owing to the insensible lithological passage of one into another, so that, with the exception of the *Belemnitella plena* zone, they will be taken together here. The first point that comes out clearly from my own work* is the apparent uniformity in composition of the Lower Chalk for the same area during the greater part of the period. For example, three experiments from the lowest, middle, and upper beds of this formation yielded 39 per cent., 44 per cent., and 37 per cent. of insoluble residue respectively, whilst at Folkestone a similar series gave 13 per cent., 16 per cent., and 18 per cent. (In these cases the upper bed was the *Bel. plena* zone.) When the two areas above-mentioned are compared together, a difference comes into view which, from its threefold repetition, cannot be due to mere accident. It is indeed merely a re-emphasising of the suggestion that the Isle of Wight is nearer the old land surface than the county of Kent. What speaks more eloquently than the 40 per cent. average of insoluble residue in the former case, as contrasted with the 15 per cent. average in the latter?

Especially noteworthy, too, is the wide distribution of Arenaceous Foraminifera during this period, every experiment having yielded a considerable number of these minute forms, whilst Professor Judd also obtained them from the Richmond boring.

* *Chemical and Micro-Mineralogical Researches on Upper Cretaceous Zones of the South of England* (London, 1893), Table I.

Yet differences are already well-marked, even when considering the above two districts only. Thus all the materials from the heavy residue of the *Plocoscyphia mæandrina* zone of Folkestone were smaller than those from the beds containing the same fossil in the Isle of Wight. Foraminifera, glauconitic grains and quartz-grains showed the same change, the latter especially being in striking contrast to those obtained from the Isle of Wight.

The species of Arenaceous Foraminifera are in the main the same, but so comparatively shallow-water a form as *Placopsilina cenomana*, of which two specimens were obtained in the Isle of Wight, was entirely absent at Folkestone.

Though in general there was a deeper-water character observable in the results obtained from Folkestone, in one analysis of the Grey Chalk from that locality, the Foraminifera, such as *Tritaxia tricarinata*, which were so prominent in the lowest strata of the Lower Chalk in the Isle of Wight, again appeared here, and were of a large size. The insoluble residue was present in larger percentage, but inorganic heavy materials were entirely absent. This is the chief exception to the sequence otherwise noticed by me.

If the chemical composition remains uniform, the change in the silicified Foraminifera is marked as we ascend in the vertical series, the predominance of Textularians which has been noted in the lower zones giving way to that of the Bulimines in the upper ones.

The question as to how far these results might be due to changes in the ocean depths so far interested me that I resolved to work out a comparison between my Arenaceous Foraminifera and those of the *Challenger* Expedition.

For the lower beds the results were as follows:

The three Textularian species now occur together at 390 fathoms. *Gaudryina pupoides* is with them at the same locality. Two other forms are only known at present at a lesser depth. Lastly, though it is true the species are not the same, yet the Bulimines are represented by five species at the above locality, viz., Culebra Island, W. Indies, and in our marls by six.

It is of importance to note, then, that the Foraminifera which predominate in the lower zones of the Lower Chalk are those which do not pass beyond the 400 fathom line. This holds good for the Textularians (with one exception).

At the present day only one or two species exceed the 420 fathom limit, *T. agglutinans* being the principal deep-sea form.

In the more central portion of the mass of the Lower Chalk it is of the greatest interest to note that all the Textularians disappear, except this deep-sea form, and a very minute species which only occurs in the higher beds and the Middle Chalk. Another type, *Haplophragmium agglutinans*, is of similar ubiquity at the present day. This change, which especially holds good for the Isle of Wight, and is in the main true for Kent, seems to have a significant resemblance to similar changes in the *Challenger* fauna.

The upper beds of the Lower Chalk, both in the Isle of Wight and near Lewes, are chiefly characterised by the presence of a particular Buliminc, *B. variabilis*, together with some of the above typical deep-sea forms.

It must not be forgotten that the Foraminifera which have here been studied are merely remnants of a great bottom-living fauna preserved under special conditions, and that the whole body of Lower Chalk non-pelagic forms, must be compared with the vast collection obtained by the *Challenger* expedition.

Until a patient and painstaking research has been carried out for each zone of the Chalk, similar to that undertaken by Mr. F. Chapman with reference to the micro-organisms of the Folkestone Gault, it will be impossible to dogmatise on this question; but these preliminary results, if combined with others, may perhaps strengthen the position that a depth of over 400 fathoms was attained ere the Lower Chalk period closed.

It has already been pointed out by Dr. Carpenter * that the Miliolines of the Chalk Marl are small and delicate, and in this respect similar to those now obtained from depths of 300–500 fathoms. Turning to the Mollusca, the evidence is very striking. Except in the very lowest beds, Dimyarian bivalves and Gasteropoda are almost entirely absent, whilst Monomyaria hold the field completely. There is a noticeable sequence here. *Ostrea* is specifically richest in the Upper Greensand, *Lima* and *Pecten* in the Lower Chalk, *Inoceramus* in the *Micraster* zones. But fortunately *Lima* and *Pecten* are abundant at the present day. Where do they have their widest distribution and most striking oceanic development? Out of 45 *Challenger* dredgings, containing genera known from the Cretaceous, made in less than 350 fathoms, *Pecten* occurred 11, *Lima* 8 times. Only twice were two species together in the case of *Pecten*, not once in that of *Lima*. It may be added that they also formed but a small percentage of the whole fauna. Between 345–775 fathoms, 14 dredgings yielded *Pecten* 8, *Lima* 5 times. At 390 f. *Pecten* has 3 species, at 450 f. 4 species, and at the latter depth *Lima* had once two species occurring together.

At greater depths the Monomyaria become inconspicuous, at the present day archaic Dimyaria being the chief representatives. On this ground therefore, the lower zones of this Lower Chalk period may have been deposited at depths of nearly or over 400 fathoms.

Turning now to the lithological aspect of the case, where are deposits most similar to the Chalk Marls now being

* *Introduction to the Study of Foraminifera* (Roy. Soc., 1858-1862), p. 2

laid down? The answer is given by Dr. Murray,* who states that the ooze most similar to the above is being formed in the south of the Gulf of Mexico at a depth of 300–500 fathoms. Again, glauconitic grains are present in the lower beds of the Lower Chalk, but cease in the upper. Similarly, at the present day, it seems to me from preliminary study that although greensands are known to extend to 900 fathoms, yet in general the presence of glauconitic grains is not marked when the depths exceed 500 fathoms.

If the heavy residue be considered, the Zircons, etc., present are found to be 3 to 5 times smaller than similar minerals occurring in such deposits as the Bargate Stone, and Bagshot Sands, and the marl cannot on this ground be a mere offshore formation. In the upper beds these minerals are altogether absent. Consequently, the conclusion arrived at is that the Lower Chalk was a coast-line ooze deposited in deep water (probably over 300 or 400 fathoms). Resuming the facts on which it is based, these are:

1. Character of Arenaceous Foraminifera, especially the disappearance of Textularian genera in the upper beds.
2. Preponderance of Monomyarian Lamellibranchs.
3. Similarity to deeper coast-line deposits forming at present day.
4. Disappearance of glauconitic grains in the upper zones.
5. Great reduction in size of heavy minerals in the lower, and complete absence of the same in the upper zones.

It must be added that there is evidence of partial re-elevation during the period, as in the case of the Totternhoe Stone, but as I have not yet personally studied this, I refrain from further dealing with it.

Belemnitella Plena Zone.

At the summit of the whole Cenomanian series is a peculiarly fine-grained yellow marl, which has been variously referred to the Lower and Middle Chalk. This breaks readily into thin laminæ, and can be at once distinguished from the Grey Chalk below, by the greater ease with which it yields to denuding influences. In the Warren at Folkestone, the band is clearly marked out as a groove in the cliff. In addition, the marl is found to contain a characteristic Cephalopod, *Belemnitella* (*Actinocamax*) *plena*, whence the zonal name.

These special features are widespread, and I can bear personal witness to the similarity of the stratum in Dorset, at Eastbourne, Folkestone, and Snodland, near Rochester. At the last three localities the type fossil has been obtained. Mr. Price mentions

* *Bull. Mus. Comp. Zool.*, *Cambridge*, *U.S.*, vol. xii, p. 51.

it from Folkestone, among some fossils sent me from Eastbourne I identified it, and found on inquiry that it came from this very position.

Finally, acting on Professor Judd's advice (who had been led to suspect its presence in this district), Mr. G. W. Card and myself spent a pleasant time at Burham, near Snodland, tracing out the zone, and were additionally successful in finding several of the zone fossils *in situ*.

The results of chemical analysis appear to bring out the important fact, that it is impossible to separate this zone from those of the remaining Lower Chalk on general lithological grounds. In Dorset the insoluble residue is nearly 40 per cent., and at Folkestone only 18 per cent., these last figures having already been mentioned in discussing the previous zone. Similarly, the fauna distinctly resembles that of the previous division, so that on all general grounds this zone may be rightly classed as the summit of the Cenomanian, or Lower Chalk Series.

If, on the one hand, the total residue and larger fauna lead to this conclusion, the preserved Foraminifera point away from the same, and link it more closely to the Middle Chalk above. Thus, in the Isle of Wight, several specimens of *Ammodiscus incertus* occurred, and one beautiful little specimen of *Ammodiscus charoides* was discovered, the latter form, to the best of my knowledge, never having been mentioned from the Cretaceous before. In addition, *Textularia minuta* and straight types of *Haplophragmium* are present. All these species, except *A. charoides*, form the main organic portion of the heavy residue in the succeeding zones of the Middle Chalk.

I submit, then, that the relations previously established still continued, viz., the land was practically at about the same distance from the area of deposition, whilst the evidence of depression is well marked. But one cannot help thinking that this fine marl represents the eve of a considerable change. Imagine a land surface sinking beneath the wave. Would not the results be precisely those we find here? Would not the fine material of the surface soil be the last to be distributed over the sea-bottom? Let me suggest that this important change may be taking place, and that the nodular condition of the Melbourn Rock above is directly due to the depression.

A further idea may be submitted to your notice. May it not be, that as the land surface disappeared, the re-arrangement of the currents may have introduced a fauna not previously present there, at any rate in abundance, but dying out as soon as favourable conditions ceased to exist. The extreme marly condition seems in England to be practically limited to that area where we have previously inferred the Upper Greensand current to have been most active. In Cambridge (judging from

Mr. Jukes-Browne's description)* the character of the zone seems very different, and much more chalky.

The Norfolk *Bel. plena* has been found by Dr. Barrois in a rock which is practically a pure chalk, at least as regards appearance, and in France (Yonne and Aube) the type fossil occurs in a distinctly nodular chalk rock.

The matter is one that requires a most careful inquiry, and in the preceding pages I have attempted to point out the direction to which my own opinions at present tend.

MIDDLE CHALK PERIOD.

Inoceramus labiatus Zone.

The next step is a short one, viz., to the view that the nodular condition of the zone overlying the last, is directly due to the currents set up by the sudden alteration in physical conditions, and that most chalky nodular beds are thus formed, whether under the influence of elevation or depression. No doubt the nearer the old land surface the more prominent the nodular conditions. This appears to be the case in South Dorset, where nearly the whole of the Middle Chalk is nodular, and it is very difficult to draw any demarcation line between the Middle and Lower Chalk.

Speaking generally, the proofs of the nodular condition of the *Inoc. labiatus* zone being due to depression are as follows: Stratigraphical reasons for such belief are to be met with in the N.E. of France, for the chalk of this zone is not nodular near the shore-line, but is so at some distance from the old land. It is of a very marly nature in the Ardennes region itself, and gradually becomes more calcareous and nodular in passing towards the departments of Yonne and Aube, where on other grounds the deepest part of the French Cretaceous Gulf seems to have been situated. Similarly, the nodular condition is still met with in the Boulonnais and at Dover, that is, precisely at those points which appear on other grounds to be regions of maximum depression in the west of Europe.

Consequently, nodular conditions are not necessary evidence of shallowing in the Cretaceous Sea, but expressions of modifications in its general relations.

In the same way, the sudden decrease in the amount of insoluble residue is not what would be expected as the result of emersion, or even of strong tendency in that direction. In the Isle of Wight the drop is from 40 per cent. to just over 2 per cent., and at Folkestone from 18 per cent. to 4 per cent.

In the Isle of Wight *Ammodiscus incertus* and *Textularia*

* *Geol. Surv. Mem. Cambridge*, pp. 55-60.

minuta occur in the heavy residue, as they do in the previous and succeeding zones, a similarity which, as far as it goes, bears striking testimony to the slight change in microfaunal conditions during the whole of the period.

As the minerals present form only one five-thousandth to one ten-thousandth of the whole mass taken, they cannot be regarded as representing a re-elevation of the sea-bottom, but are rather silent witnesses to the presence of the current which caused the arrangement now observed.

Mr. Jukes-Browne kindly informs me that the analysis of a specimen from this zone obtained at Harston, Cambridge, and which yielded over 11 per cent. of residue is a piece of a more marly portion, and not of typical rock as now defined. I infer from the description in the Survey Memoir on Cambridge that the marly partings are more distinctly separated from the chalky layers than is the case in our southern counties.

The greatest difficulty undoubtedly is that of the change in the palæontological characters. The fauna has practically no relations with that of the Lower Chalk, but is in many ways closely bound up with that of the succeeding zone. But the forms that now present themselves are not such as would imply a decisive bathymetric change. There is no reappearance of Gasteropoda, with the exception of a *Rostellaria* mentioned from the Isle of Wight by Dr. Barrois. Dr. Nicholson has observed that deep-sea forms are usually widely diffused, their range depending chiefly on temperature and being influenced mainly by oceanic currents. As regards minerals, there is at Folkestone a reappearance of a few Zircons, but these are very minute.

The break in the faunal characters seems to me to be produced by physical alterations, the change in current directions caused by the sinking of the land, bringing about the introduction of new species of genera already well established in the Upper Cretaceous sea. We must fully admit the difficulty, but the facts already brought forward seem to me to weigh heavily in support of the views here being enunciated.

But it will be said, it is preposterous to admit the possibility of current action at such depths as I claim for this deposit. The objection is a very rational one, and I felt its weight when first collecting these notes. But in looking over *Deep-sea Deposits*, at p. 51 I found a reference to the formation of "chalky nodules, 2 to 3 cm. in diameter, *apparently derived from the deposit*" (these are the terms of the description). They occurred at a depth of 1,700 fathoms, in the very centre of the Gulf Stream, between St. Thomas and Bermuda, and a note was added at the previous station, that during the ten hours of sounding operations the current was running uniformly at the rate of $3\frac{1}{4}$ miles the hour.

The deposit was blue mud, and one asks oneself the question, if chalky nodules are produced in this deposit, which contains only 12 per cent. of carbonate of lime, what would be the result if a similar current were passing over a pure globigerina ooze. Of course, it is not probable that it is the surface-flow that causes the nodules, but a ground-current flowing in the opposite direction. The many cases in which nodular beds occur at the junction of terrigenous and calcareous sea-deposits seems to lend considerable weight to the above hypothesis.

Terebratulina gracilis Zone.

The depression probably continues to about the middle of the *Terebratulina gracilis* zone period, but it should not be allowed too wide a limit, and this for several reasons.

In the first place, the marly partings which occur from time even in our own area, serve as reminders that these beds were not totally removed from land influences, whilst in parts the abundance of thick-shelled *Inocerami* and *Spondylus spinosus* show that the conditions were still favourable to the development of such types. At the same time, here too the conditions are relative, for the *Terebratulina gracilis* zone near Dover contains barely $1\frac{1}{2}$ per cent. of insoluble residue, and only yielded the remains of *Terebratulina gracilis* and other delicate organisms. In addition, practically no heavy residue remained behind for investigation. Yet in this very period almost every type of deposit was being formed. Greensand in Westphalia, marls with 68 per cent. of clay in the Ardennes, nodular beds in Dorset, and sandy chalk in Devonshire; what a lesson it teaches as to the gradual change which has taken place in the southern counties, and how here a condition has been attained after a gradual historical evolution, whilst in other districts the various stages are represented in a striking and significant manner.

The following is suggested as the succession representing the variation in character of the oozes as the various stages of depression are passed through. Greensand; a layer with derived materials having transition characters may intervene; Marls rich in clayey materials; Marls rich in calcareous materials; Fine marls; Nodular marly chalk; Alternate chalky and marly partings, the latter usually very thin; Hard white chalk.

Any member may fall out of the series. Thus in Russia there is direct passage from greensand to chalk, just as to-day off the coast of Portugal there is direct passage from greensand in 600-900 fathoms to globigerina ooze in 1,000 fathoms. Similarly in Touraine, the marly chalk is succeeded by a micaceous chalk, as might be expected if a mica-bearing rock-region were being attacked by the sea. In my work previously cited (p. 8), I pointed out the probability that the Lewes and Brighton district was one of the areas affected by a great Cretaceous current. I based this opinion upon the discovery of fragments of wood and large pebbles in the various chalk zones of the neighbourhood. To that may be added a few further suggestions.

If this area were on a current line, it would present certain features peculiar to such a position. During the whole of the upper Turonian period there are such distinct traces. This is the case here, for in a total thickness of forty feet, nodular beds are mentioned four times, and marly beds three times. More than this, the thick-shelled forms, such as *Spondylus spinosus*, are almost invariably found in chalk beds immediately succeeding such a clayey or nodular band. I have examined many statements as to the discovery of *Spondylus spinosus*, and find that in almost every case it either has been obtained from nodular beds themselves, or from true chalk in immediate association with beds of such a character.

Therefore these thick-shelled forms were not probably the true natives of the district under discussion, but shallower types brought there under the action of currents. Of course, the current that could bring the free-swimming larva of the mollusc, could obviously bring the food necessary for its successful growth and development.

But a further point to note, is the abundant fish-fauna of this district. Why is this? The answer perhaps is not far to seek. The current will evidently carry along with it large amounts of material derived from the littoral area, and far more suitable to a piscine palate than the usual minute pelagic fauna of an oceanic region. The result would be that comparatively shallow-water Teleostean fishes, such as *Beryx*, would have their range greatly extended seawards, whilst the rich increase in food-material, would tend to bring together large numbers of predatory fishes, especially sharks, such as *Lamna*, etc. In this way, perhaps, the discovery of such a rich fauna may be explained. I cannot deal with this matter more fully at present, but leave it as a subject for more general discussion.

In the upper part of the *Terebratulina gracilis* zone, the residue after treatment with acid rises to $3\frac{1}{2}$ per cent., so that there are already signs of that movement of elevation to which the nodular condition of the Chalk Rock may be due.

Chalk Rock (Holaster planus Zone).

The Chalk Rock, first defined by Mr. Whitaker, is like the Melbourn Rock, an important nodular bed, and is amongst the difficulties with which the historical geologist has especially to deal.

Both in England and France there are a large number of facts, pointing to re-elevation of some of the old land surfaces, but without marked effect on the chemical composition of the Chalk in our own district. Indeed, this at least seems very clear, that as in the preceding nodular bed, and as in one yet to be mentioned, the change in the calcareous percentage is slight compared with the alteration in general appearance, at any rate as far as the S.E. counties are concerned.

Near Dover this zone appears to be represented by a beautiful, hard, creamy-white limestone, in part containing very dark flints. (And here be it noticed that flints in the Middle Chalk first make their appearance in connection with evidences of change due to land currents.) The limestone is not truly nodular, but of a somewhat lumpy character. In the Isle of Wight the Chalk Rock is hard and nodular, with an especially prominent line of green-coated nodules. Mr. Jukes-Browne has further favoured me with the information that in Dorset it has enclosures of glauconitic sandstone of several varieties, and also very large grains of quartz and glauconite, one layer being really a glauconitic grit.

In Devon this zone appears to be represented by a layer of hard nodules only.

In Oxford and Bucks a hard, yellowish rock contains in addition to green-coated nodules and glauconite grains, the sea-urchin *Holaster planus*, which we find mentioned by Norman from the Lower Chalk of the Undercliff, and which has been used as the type fossil for this zone by Dr. Barrois. Gasteropoda of Trochoid types (*Turbo*, *Solarium*, etc.), are abundan in some parts. It is very interesting to note that it is the above genera that especially tend to attain greater depths than the other univalves.

Before the Midland Chalk Rock was well understood it was classed as Upper Greensand, as it formed a low ridge at the base of the chalk hills, similar to that produced by the latter at the foot of the Downs in our southern counties. It has now become, like the Melbourn Rock, a most important means of determination of level in borings, where fossils are not easily obtainable.

From the point of view of the detrital minerals, the evidence is favourable to re-elevation. The quartz grains reappear in large numbers, glauconitic grains being also very prominent. Tourmaline has also been detected by me; the last zone where it was noticed being the Grey Chalk (*Holaster sub-globosus* zone). Hornblende and Augite have also been observed in the heavy residue. I cannot admit the actual emersion of the S.E. counties, but hold that the nodular condition is due to the currents set up or modified by the reappearance of old land surfaces above the ocean level, such elevation taking place in the W. of England.

The Middle Chalk closes with the deposition of a dark band of clay overlying the Chalk Rock.

The palæontological break between the Middle and Upper Chalk is not so marked as in the case of the junction of Middle and Lower Chalk. This is easily explainable if we remember that the circumstances had been essentially unfavourable to the development of a shore fauna, and that only those species most suitable for distribution by current action would be capable of being brought to such a distance from the shore line. Of the 18 species which are common to the two divisions (Turonian and Senonian), nine are Echinodermata, three Brachiopods, and six Monomyarian Lamellibranchs, a fauna which does not give us much idea of the near presence of land. It may be asked, what depth would you assign as the average for the Middle Chalk? In deciding the question, it is perhaps not fair to take the fauna of a chalk bed deposited under current conditions. The presence of *Terebratulina gracilis* is perhaps the chief test remaining to us. The nearest representative at the present day, *T. caput-serpentis*, ranges from 0 to 1,180 fathoms. It has already been pointed out that there are reasons for regarding the Upper Grey Chalk as having been deposited at 500 fathoms or over. Two species of *Terebratulina* have been obtained from 600 fathoms, so that I would assign this figure as perhaps the nearest approximation. In England, *T. gracilis* is a comparatively scarce fossil, whilst in the more littoral areas of France it occurs sometimes in enormous quantities in certain beds. Probably the English Chalk is very near the deeper limit of the bathymetrical range of this species.

Typically the Middle Chalk presents an interesting sequence. At the base is the nodular bed, the Melbourn Rock, containing large Monomyaria. This shades slowly into an almost pure white limestone, devoid of large Mollusca, and containing only *Terebratulina gracilis* and other delicate organisms. This condition is met with at about the centre of the Turonian strata. The conditions are then reversed, the limestone becomes more and more marly, nodular bands also reappearing, until at length these attain their maximum in the Chalk Rock, which itself is surmounted by a dark clay.

UPPER CHALK.

The division into zones will be difficult to follow in this case, and space forbids of more than general discussion. Probably the Upper Chalk is the most difficult for correct interpretation of all the three divisions, although at first sight apparently the most easy. Here, at any rate, is definite evidence of a great submergence, far exceeding those of the preceding periods. The broad features undoubtedly point in this direction. It is only the uppermost beds in Scotland and Ireland that are of typical calcareous character, it is only these highest strata that are found extending far into the South and West of France, or becoming pure limestones on the Belgian continental frontier. The purity of the chalk, the absence of any traces of a land, and the deep-sea character of the marine fauna, all lead to the same general conclusion.

The homogeneous nature of this great mass is in reality only partial, and in our district it is possible to subdivide it readily into three main divisions, a flintless series separating two groups rich in bands of this material. The first is the one which at once attracts attention as being the familiar flinty chalk of Ramsgate and Broadstairs. Close observers have found differences, both in the characters of the flints and the nature of the zonal fossils. In the lowest part of the whole there appears to me to be a small stratum marked by the presence of large, irregular rose-coloured flints. At first this struck me as a mere accident, but after meeting it both in the Isle of Wight and at Eastbourne, and finding it especially mentioned by De Lapparent as a typical member of the *Micraster cor-bovis* zone on the North coast of France, I could no longer regard it as a mere trivial detail, but as an important and widespread physical feature.

On the value of the palæontological separation into *Micraster cor-testudinarium* and *M. cor-anguinum* zones, I do not feel competent to give an opinion, but Dr. Barrois has found that there is variation also in the character of the flints, those in the former case being irregular (*cariés*), whilst in the latter they present, on being broken open, a series of differently-tinted layers, and have therefore received the name of zoned flints.

Indeed, the distribution of flints is a question which possesses a special charm for students of this great phase in the physical geography of the past, and I would call your attention to the article on the subject of "Disseminated Silica in the Chalk considered in relation to Flints,"* by so able an exponent of the subject as Mr. Jukes-Browne, as also preceding papers in the same magazine in answer to suggestions by Mr. Abbott. His first conclusion is important, viz., that there is no definite relation between the occurrence of flint and the absence or presence of soluble silica in the surrounding chalk. His second suggestion is that the decay of sponges set up reactions which caused first the solution of the scattered spicules and ultimately the precipitation of the silica in the form of flint.

In general, the flints appear to be getting smaller as we ascend in the scale. Do they finally die away gradually?

The answer is distinctly in the negative in some cases. This brings us directly to the second division, which in our S.E. counties will be found to be apparently almost devoid of flints, we may term it the flintless member of the Upper Chalk, and it corresponds very closely with the zone of *Marsupites*

* *Geol. Mag.*, Dec., 1893, p. 541.

ornatus. Almost everywhere it opens in some peculiar or special manner.

This is well seen just below the N. Foreland lighthouse, where the flinty chalk closes with a thick layer of tabular flint, the well-known Three-Inch Band, which has been shown by Mr. Whitaker to extend over a very considerable area.

In the Isle of Wight the break is of a different nature. Here the line is drawn at a nodular bed, which forms a prominent feature at the foot of the Culver Cliff. This represents a change similar to those previously mentioned, but on a much smaller scale. The percentage of clay rises to 2·5, as compared with 1·5 and ·85 given by samples from the zones below and above. Consequently, this bed does not point to any great break in the sequence. There is a noticeable tendency to the formation of tabular flints at the summit of the *Micraster cor-anguinum* zone, two broad bands being especially marked, as at Berling Gap to the W. of Eastbourne, but these cease abruptly at the summit of the zone.

Only at Wells, in Norfolk, have I met with tabular flints in the *Marsupites* zone, but here there are reasons for regarding them as productions of a later date.

The *Marsupites* zone is, by its freedom from external impurities and its rich and varied deep-sea fauna, one of the most generally interesting of the zones of the Chalk. The typical *Micraster cor-anguinum*, so familiar to most of you, in reality occurs normally in this zone. The reason of the apparent anomaly is this. Formerly the *Micraster cor-anguinum* and *Marsupites* zones were classed together under the first name. This arrangement has often surprised me, as it has always seemed more natural to have grouped the two *Micraster* zones together.

The incongruity of the arrangement struck Dr. Barrois, who broke up this unwieldy and somewhat unnatural division into the above minor sections. The *Marsupites* zone carried with it the type fossil which had originally given its name to the whole, whilst more aberrant forms of the same characterise the *Micraster cor-anguinum* zone, as now limited. The *Marsupites* zone represents perhaps the period of maximum rest, and possibly that of maximum depression in our district. Three analyses made by me gave the insoluble residue as not more than 1·3 per cent., a condition only paralleled in the zone immediately following.

The fine residue here was of great interest, consisting of a number of minute rounded ferruginous grains, which simulate casts of Foraminiferal tests. These form, however, only one ten-thousandth part of the 80 grammes of chalk dealt with.

Just as the *Marsupites* Chalk begins, so it closes, without any apparent gradation to the flinty chalk succeeding it. This latter includes the well-known *Belemnitella mucronata* zone, which on the continent has been further minutely sub-divided. In general, the presence of the type fossil, the re-appearance of flints, and the great spread of this zone over Northern Europe at large, have caused it to become a peculiarly interesting subject of study.

As this zone attains here thicknesses of from 200–500 ft., it is readily to be understood that there is room for considerable variation in its details.

One of the most striking exceptions to the regular deposition of the pure white chalk caused some sensation two years ago, when Mr. Strahan discovered a deposit of phosphatic chalk at Taplow, similar to those met with in France and Belgium. As yet, however, this remains our only English representative.

Mr. Strahan thus reviews the question :

> " MM. Renard and Cornet concluded that the phosphatic granules in the chalk had been brought together to their present positions by the action of currents. But they go further, and maintain that the Chalk is a deposit formed in comparatively shallow water near land. To the reptiles and fishes of the littoral areas was due the concentration of phosphatic materials, and the subsequent phosphatisation of the microscopic organisms with which it was mingled." *

I have endeavoured in the preceding remarks to combat the view that Chalk as such is not a deep-sea deposit, whilst fully admitting that chalk in France and Belgium was laid down in far shallower water than was the case in our own country.

Mr. Strahan admits that the Taplow Chalk might have been distributed under the influence of marine currents, that the granules may have been drifted from a distance, and that phosphatisation took place before the drifting of the materials. But he arrives at the same conclusion as I have mentioned previously for the formation of nodular rocks, a view for the origin of the latter also maintained by M. Janet in France. He asks how it is that there is no trace of mud or mineral fragments, and adds, from whatever direction the rock contents were drifted, they came from a region almost unreached by mineral sediment.

His conclusion is, that possibly the abundance of little coprolites pointed to the presence of banks or hollows in the Chalk Sea, frequented by small fishes, to whose efforts were due the phosphatisation of the organic contents at this spot.

I may add, that the Foraminifera, studied by Mr. Chapman,† present great features of interest. No less than thirty had not been previously described from the Chalk, and five of these were quite new to science. Of the 98 found altogether, 60 are probably bottom-living forms.

The following details of the distribution of these species at the present day may be of interest :—

5 occur together at Raine Island, S. Pacific, 155 fathoms.
5 other species off Japan, 345 fathoms.

* Strahan, A., *Natural Science*, vol. i, p. 286. (June, 1892).
† Chapman, F., *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 516.

11, nearly all different from preceding, in Pteropod ooze, off Culebra, S.W. Indies, 395 fathoms.

In this Pteropod ooze occur also no less than 18 of the pelagic forms found at Taplow, and 3 typical bottom-living forms met with in the Chalk Marl, but not at Taplow.

5 bottom-living, 11 pelagic, off Sydney, 410 fathoms.

10 „ 6 „ „ Tahiti, 420 fathoms.

The three preceding have great general resemblances.

6 bottom-living, 8 pelagic, Pernambuco, Brazil, 675 fathoms.

Not a single Textularian was recorded from here, though in the previous three deposits they were extremely abundant.

After this depth is passed, only a few special forms are recorded. It will thus be seen how many species present in the oceans at the present day are also Cretaceous forms.

I am inclined therefore to the conclusion that these Foraminifera have been transported by current action, not from a shore line, but from considerable depths, and that this explains the absence of any mineral materials.

I shall be happy to show my list of Foraminifera to any one interested in this question, this list having been prepared from the *Challenger* volume on these organisms.

It has been noticed above that from the Chalk Rock up to the *Marsupites* zone there is a gradual reduction in the size of the contained flints, a great deposition of tabular character marking the cessation of the formation of these siliceous nodules. The question has arisen in my mind, Is this to be connected with sinking of the sea-bottom, and correlated with a distinct decrease in the size of the sponges then prevalent? If such be the case, the reappearance of flints would then serve as proof of the commencement of an era of re-elevation.

If flints be such evidence, then we must admit re-elevation from the *Marsupites* period onward, at least in the S.E. of England, for the flints appear to again gradually increase in size, until they attain the gigantic proportions of the paramoudras of Norwich, or of the large irregular flints of Studland Bay. Nor need the existence of a pure chalk in the upper zones surprise us, for an area which had undergone great submergence would have all the more easily denuded materials removed by marine action, and Cretaceous strata with high calcareous percentage might be then formed comparatively near the shore-line. I merely throw out this suggestion, which is somewhat borne out by the fact that Gasteropoda are more numerous in the higher beds than in those of the lower portion of the Upper Chalk.

Beyond this brief statement, I must frankly confess that the idea has been quite recently formed, and I have not therefore yet been able to submit it to those tests by which it must either stand or fall.

The principal points now submitted for discussion are these:

Viewed in its general aspect, the Chalk Period bears evidence

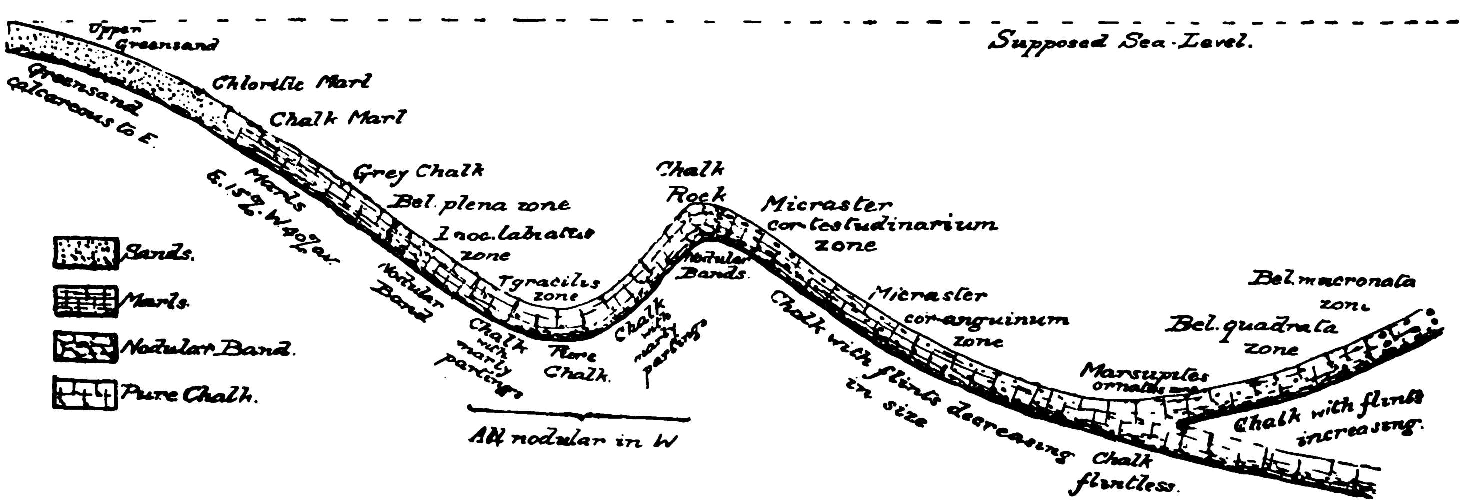


FIG. 3.—DIAGRAM TO ILLUSTRATE THE SUGGESTED RELATION BETWEEN VARIATIONS OF DEPTH AND NATURE OF DEPOSIT, AS PRESENTED BY THE UPPER CRETACEOUS ZONES IN THE SOUTH OF ENGLAND.

The bifurcation on the right indicates the two possibilities (elevation or depression) referred to on page 239.

of the almost continual gain of depression over elevation influences. This is proved by the overlap of the higher over the lower beds, by an increasing percentage of carbonate of lime, and by the gradual disappearance of all but a pelagic or deep-sea fauna.

The exceptional conditions, viz., nodular beds, phosphatic chalk, marls, and clays, may all be explained as the products of the action of currents, resulting from physical changes due either to movements of elevation or depression.

That the Cretaceous Sea in the S.E. counties has been under deep-sea conditions (possibly over 500 fathoms) ever since the closing of the Cenomanian epoch, and that the percentage composition of the chalk has been but slightly affected by the causes which gave rise to the change in physical conditions.

In studying each zone separately, it appears to me that the following points must be observed if we hope to arrive at any right conclusion.

1. Thickening or thinning of the zone. I may state here, that, if time and space had permitted, wealth of evidence could have been brought forward to show how regularly these changes take place from point to point, calcareous zones thinning landward, arenaceous zones thinning seaward.

2. The change or uniformity in chemical character, and the nature of the fine detrital materials.

3. The larger fauna in relation to probable zoological distribution and change due to physical causes.

4. The micro-organisms, especially the Foraminifera and Ostracoda, as terms of comparison with the modern deep-sea fauna

5. Its relation to the zones immediately above and below.

6. The actual structure of the rock. This varies greatly from the chalk rich in Foraminiferal tests (as in the Chalk Rock), to one practically consisting of a calcareous cement only, devoid of apparent organic fragments (as in the *Belemnitella mucronata* zone of the Isle of Wight). This part of the subject has already received much attention from Mr. Hill.

The history of the zonal sequence as here presented may be resumed thus:

The *Upper Greensand* (*Pecten asper* zone) is the expression of coast-line conditions, the currents transporting shore materials being sufficiently strong to make their influence felt for over 300 miles from land.

The *Chloritic Marl* represents the denuding effect of the advancing sea upon the sinking land, the *Pecten asper* zone being a special feature in this sea.

The *Chalk Marl* and *Grey Chalk* were deposited in areas of gradual subsidence, but still within the influence of currents from the land, and cannot therefore be strictly termed deep-sea deposits. In our S.E. counties they approach most nearly to the latter condition.

The *Belemnitella plena* marl is the product of the final denudation of an old land surface, and *Bel. plena* may represent a deep-sea fauna admitted owing to the change.

The nodular bed (equivalent to *Melbourn Rock*) at the base of the *Inoceramus labiatus* zone is the expression of the action of currents, resulting from the disappearance of an old land surface, the change in the zonal fauna resulting therefrom. Indeed, if there were the junction of a large marine area with a larger external sea, there would result an inflow of surface water from the latter, carrying with it part of its pelagic fauna, whilst at the same time the ground current produced would extend the area of distribution of those forms having free swimming larvæ, granted that the latter found suitable conditions for their development.

The higher beds of this zone pass insensibly into that of *Terebratulina gracilis*, the maximum depression for the Middle Chalk period being at or about the time of the laying down of the central beds of this zone.

From this point onward, a minor movement of elevation commences, finally resulting in the formation of another nodular series, culminating in the *Chalk Rock*, a band of clay closing the Middle Chalk period.

The *Upper Chalk* represents the almost continuous gain of depression over elevation (subject, however, to the possibility mentioned above), although a few nodular beds, the phosphatic chalk of Taplow, bands of clay, as at Speeton, in Yorkshire and Birchington, in Kent, may point to changes resulting from minor alterations in the land relations.

Suggestions as to depth have been added, so as to lend more definiteness to the discussion, and more clearly to define my position in relation to existing theories.

Hitherto I have ignored the controversial aspects of the question now before us. But in reality, the whole subject is one which has attracted the notice of most able observers, and has sharply divided these into two schools, one advocating a littoral, and the other a deep-sea origin for the Chalk.

Let us briefly consider the position of the advocates of littoral deposition. The extreme position in this direction was undoubtedly that taken up by the late distinguished conchologist Dr. Gwyn-Jeffreys, who in his Address to the Biological Section of the British Association (*loc. cit.*) remarks, after examining the Molluscan evidence. "I should infer that the depth might have been from low-water mark to 40 or 50 fathoms."

Fuchs* has attacked this question, and has endeavoured to show from a general point of view how mistaken was the interpretation of facts as set forth by Dr. Gwyn-Jeffreys. My own objection is that nowhere in his list does the latter state where the various mollusca occurred which serve as the basis of his

* *Jahrb. für Min. Geol., Beilage-Band II*, 1882-1883, p. 548.

conclusions. I have also been over the fossil forms at the British Museum, and find very different results, but as Dr. Woodward and Mr. Etheridge accompanied Dr. Gwyn-Jeffreys during his own examination, they may perhaps be willing to favour me with further statements on the subject.

Indeed, in most cases the occurrences pointed to conclusions the significance of which has been shown in the earlier pages of this paper. Thus, four Gasteropod genera have been obtained from Hamsey, *near Lewes* (including our only known English Upper Cretaceous *Voluta*). I find from a note by Dr. Barrois that the *Bel. plena* zone is exposed at this locality.

Turbo, *Trochus*, and *Solarium* are from the Chalk Rock of the Midlands. A few others are from the Norwich Upper Chalk, that is, from the highest beds known in England. *Pleurotomaria* seems indeed to be the only ubiquitous Gasteropod form in the southern area.

In my further remarks on this point I would note that three works have been especially examined in forming my conclusions, viz., *The Geological Survey Memoirs on Cambridge and the Isle of Wight*, and Westlake's *Tabular Analysis of Dr. Barrois' Results.* From these I find that the Gasteropoda are generally extremely rare, the great majority of Upper Cretaceous forms coming from the Totternhoe Stone, which I fully admit to be due to re-elevation.

In the course of an extended research, Dr. Barrois only found three univalves, two *Rostellarias* in the Isle of Wight and Dorset, and one *Pleurotomaria* near Beachy Head.

The latter occurred in the *Micr. cor-testudinarium* zone, which is described as being distinguished by its fauna, irregular flints, sponge band, and finally by *several true nodular beds.*

I cannot carry the subject further, but will only state that in the Isle of Wight all the students of Cretaceous geology put together have succeeded in discovering six univalves in the Lower, one in the Middle, and *none* in the Upper Chalk.

But it will be urged, this is due to the fact that the Gasteropoda had shells of aragonite, which were dissolved away. This must be conceded; but why should their casts be preserved for us almost entirely in chalk of a nodular character? And why, when they are preserved in such quantity in the greensands and marls of Germany, should they be so much reduced in our own greensands and marls? Either the Gasteropoda have been dissolved, or they were originally absent, and taking all questions into consideration, the latter view seems the more probable.

I have already generally discussed the question of the distribution of Lamellibranchs, and will not repeat it here.

The appended table shows the relative importance of the various Molluscan groups as indicated by their percentage relationships. (Where the total number is small the actual number is given in brackets below the percentage.) It shows that from the

Bel. plena zone onwards the Monomyaria are the predominant type forms.

			SOUTHERN COUNTIES: ENGLAND.										
	Greensand, New Jersey.	Upper Chalk, Germany.	Blackdown Sands, Devon	Upper Greensand.	Lower Chalk.	Bel. plena.	Inoc. labiatus.	Tereb. gracilis.	Chalk Rock.	Micraster Zones.	Marsupites.	Bel. mucronata.	Chalk Rügen, Germany.
Percentage of—													
Monomyaria . . .	14	23	8	49	74	100	80	100	100	95	93	80	83
Dimyaria	41	43	69	30	14	—	—	—	—	5 (1)	7 (1)	—	8·5 (2)
Gasteropoda . . .	45	34	23	21	12	—	20 (1)	—	—	—	—	20 (2)	8·5 (2)
In a total of	282	282	99	70	38	9	6	11	8	20	15	10	23

It will thus be seen that even on Molluscan evidence alone I am led to a very different conclusion from that arrived at by Dr. Gwyn-Jeffreys.

The Sponges have not yet been studied by me in detail in relation to their zonal distribution. Dr. Hinde* has discussed the question of depth-evidence without coming to any definite conclusions. Of course, if relations are fully established between the formation of flint, and the existence of sponges, these organisms will become of the greatest importance in future discussions.

Basing themselves on micro-organisms mainly, Professor T. R. Jones and Dr. Woodward have lent their support to the view that chalk was deposited in comparatively shallow water, How far the latter endorses this theory I am unable to state, for Dr. Gwyn-Jeffreys merely quotes his evidence from the study of the Ostracoda as being in favour of the hypothesis. Professor Rupert Jones, in his papers before the Hertford Natural History Society, has given his weighty support to this solution of the question. Not being competent to follow him over the ground, on the which he is so undoubted a champion, I can only hope that his studies will not tend to invalidate the conclusions here set forth. Whilst in England, therefore, the shallow water aspect has been upheld by most competent authorities, in France some of the most brilliant students of Cretaceous geology have arrived at similar results for that country.

Whereas in England, it may be that this view has gained ground, owing to a study of the whole not having been divided into that of its component parts, in the latter case the results are probably due to the fact that the Cretaceous strata of France have been deposited far nearer the shore-line, especially in the N.E. departments and in Belgium. To the French school we owe a great debt of gratitude. Thanks to M. Hébert, M. de Mercey, Professor Gosselet, Dr. Barrois, and others, zones are

* *Sponge Spicules of Upper Chalk of Horstead*, Munich, 1880, p. 75.

now thoroughly recognised and established, enabling us to start afresh in search of the true history of this interesting epoch.

M. Hébert* published a series of classical papers which have tended to revolutionise our conceptions of the Chalk. He appears to incline to the view that the nodular bands are in reality definite breaks in Cretaceous history, whereas I have endeavoured to show that these may be entirely due to changes in physical conditions and current relations.

Dr. Barrois has not committed himself so definitely to this position, and M. de Lapparent appears to lean to the explanation more commonly accepted amongst English geologists. M. Cayeux, whose studies of the chalk residues, glauconite, etc., are of a most interesting and wide-reaching character, has come to the conclusion that the chalk of the Nord is terriginous in origin, but does not extend this view to the Chalk as a whole.† I fully agree with him in the first proposition. To only recall a case or two: The *Inoc. labiatus* and *Tereb. gracilis* zones of Folkestone have about 4 per cent. of insoluble residue, whereas in the Ardennes and Aisne this rises to over 40 and even 60 per cent.

But with others who apply this to the Chalk as a whole, we are not entirely in accord.

This will be best seen if the position be considered which has been taken up by Dr. Murray and M. Renard in the *Challenger* report, the latter writer being a strong supporter of the shallow-water origin of the Chalk. Thus, on p. xxviii, Deep Sea Deposits, they point out that mineral particles, evidence of mechanical action, variability of residue, chemical analysis, character of organic remains, and position of Cretaceous Sea all show the shallow-water origin of the Chalk. Also modern deep sea deposits disagree with the Chalk in the poor representation of Gasteropods and Lamellibranchs amongst their fauna.

My answers to these objections will be taken *seriatim*:

Mineral particles.—In pure chalks these are either almost entirely absent, or too minute in quantity to suggest a littoral origin.

Evidence of Mechanical Action.—This, it is maintained, here reveals only that the Chalk was sufficiently near land to be affected by the currents resulting from changes in the physical relations, but that otherwise it was subject to deep-sea conditions.

Variability of Residue.—The chalk in S.E. England varies but little in quantity of residue, in fact has never less than 95 per cent. of $CaCO_3$ from the base of the Middle Chalk onwards. (The silica of the flints, if distributed, would to some extent modify these percentages: Prof. Prestwich has suggested that it may rise to about 6 per cent. of the whole.) The presence of marls and nodular beds affects the results, and point to the existence of land at a moderate distance, but not in immediate proximity.

Chemical analysis follows the above.

* *Bull. Soc. Géol. France*, 2de série, vol. xx, p. 605, *et seqq.*
† *Bull. Soc. Géol. Nord*, vol. xix, p. 253.

Character of organic remains and *Molluscan representation* have already been considered.

I will only mention, in case of misunderstanding, that the Foraminiferal (arenaceous forms only) succession proposed here is as follows:

Upper Greensand.	Lower Cenomanian.	Upper Cenomanian.	Middle and Upper Chalk.
Orbitolina			
Textularidæ	Textularidæ	×	×
Buliminidæ	Buliminidæ	Buliminidæ	×
Ammodiscidæ	Ammodiscidæ	Ammodiscidæ	Ammodiscidæ

× implies that only minute forms, or forms now known to be typically of deep-sea character, continue.

Position of Cretaceous Sea.—Here two points come into view, one, that the littoral and coast-line deposits of the Cretaceous Sea are similar to those forming in the oceans and open marine areas of to-day, and not to those laid down in land-locked seas.

Secondly, that while its length is that of Europe, and possibly even more, yet that its breadth appears to be far less than that of the present great oceans, and indeed that the whole is far more comparable with the Mediterranean. Consequently two suggestions may be made here, one that the characters of the Cretaceous strata must be studied in connection with the oceanic deposits of to-day, the other, that as regards depth, those relations should *at least* be conceded which are found in the Mediterranean. This would give us not only depths of 500 fathoms, but quite a considerable area over 1,000 fathoms, and even up to 2,000 fathoms. More than this will not at present be asked, and the strata deposited under these deeper conditions are probably hidden, far from the ken of man, under the waters of our northern seas, or beneath the vast pile of denudation products brought by river and ice, from mountain and highland, which has built up the great North European plain, skirting to-day the old Hercynian land.

We might linger long on these physical relations, the Eastern and Western extension of the Continents, the old Palæozoic islands, the strength of currents, and the absence of volcanoes, but time and space call on me to close these remarks.

I have limited myself more especially to a consideration of the changes which have taken place in our own S. E. counties, and desire to place these suggestions before you, not in the spirit of dogmatic assertion, but in the hope that they may lead to discussion, valuable to myself especially, and also helpful to other students in the same line of study. I trust that those who are engaged on this wide and interesting subject will not hesitate to apply a searching criticism to the ideas here set forth, and will at the same time give us the benefit of the wide knowledge obtained by them during investigation carried on in the field and in the study.

GEOLOGY IN THE FIELD AND IN THE STUDY.

By HORACE B. WOODWARD, F.G.S.

Being the Presidential Address delivered 2nd February, 1894.

GEOLOGY IN THE FIELD.

NO branch of science is more generally attractive and popular than that of Geology. I say this confidently, and in spite of assertions that the subject is "played out."

It may be true that fewer individuals take up Geology as a profession; from a business point of view there are no temptations to do so. Our science, however, has always owed its main progress to those who, like William Smith, and Sedgwick, and De la Beche, are to be regarded in the highest sense as amateurs; men, and women too, who have toiled in pursuit of knowledge for the love and honour of the work, without heed to the recompense given for their services. Such must be the case with every earnest student of the science. "Red lions" may occasionally growl if they do not get enough to live upon; but no enthusiastic student would wish to exchange the field of Nature for that of commerce, or be an advocate that scientific work be restricted to a daily period of eight hours. In saying so much we withhold not our sympathy from the industrial worker, upon whom in great measure we depend for our existence, though we may not all of us approve the modern doctrine that workers in science or art should be paid less because their work is interesting, while the scavenger is entitled to the highest wage.

The few who are able to devote their whole time to science may well marvel at the large amount of work done by the many who are able to give only their spare time to geological studies. To them science rightly has a recreative aspect, and they turn to it often with a freshness and vigour that enhance the value of their productions; for, as Sedgwick remarked in 1831, "the higher intellectual powers may be cramped by a too exclusive devotion to the pursuit of natural truth."

The history of geological progress is full of interest, but when we compare the past with the present and contemplate the future some feelings of dismay are sure to arise. Each succeeding generation finds not less, but more to do. Our population does not decrease, so we need not be distressed on that account. The difficulties are with the individual, who desires to keep acquainted with the results of geological work. He is forced nowadays to take more and more of his knowledge second-hand;

for original articles are not only too numerous to be read, but often too technical to be understood. The advances are made chiefly by specialists, many of whom write in cipher; whose ways are dark, and whose language is by no means plain.*

This can hardly be avoided as subjects are investigated more and more minutely. Contributions to scientific progress are not to be judged by their immediate utility, nor even by their intelligibility; but it must always be remembered that it is the outcome of work, not the detail itself, that advances knowledge. The particular work, whether in the field or in the study, must, as a rule, be accomplished single-handed. Details of local geology are full of interest to the worker. He may spend many days in the effort to unravel the structure of a particular area, and if he goes over the ground subsequently with a friend, that friend, enthusiastic enough in other respects, may care not one whit where in particular the geological boundary-lines were drawn. The general structure of the district, the relations of the rocks to the form of the ground, the natural history of the formations, would attract and interest, and rightly so; but not the details of the mapping, unless they concerned some scientific question, or matter of economic importance.

So also in palæontological and petrological work. Moreover, in every department new terms are continually being introduced; so that those interested in the study of words, or the compilation of dictionaries, cannot keep pace with the additions. Curiously enough, a large number of the new terms are associated with changes in the structure of rocks and fossils—with metamorphism and morphology; and what is most unfortunate is that each "Doctor" seems to prescribe different terms, so that the complaint becomes aggravated. In reference to these sources of embarrassment to the student, the editor of *The American Geologist*, in lately commenting on a paper by Hyatt on "The Terms of Bioplastology," pleads that "a spirit of philanthropy will leave it undisturbed."† This, however, appears to be a forlorn hope.‡

We may be thankful that individuals arise who are content to work at details interesting to themselves and but few besides, for the results may render a service to science when they are translated and made intelligible to geologists in general. It may be necessary to publish all particulars of such work, so that others who follow in the same path may "read not to contradict and confute, nor to believe and take for granted; . . . but to weigh and consider." I have at times had occasion to lament the want of detail in papers that deal with districts at which I have been working, because I could not find a clear statement of all the

* See remarks by Hyatt, quoted by Prof. Blake, *Proc. Geol. Assoc.*, vol. xii, p. 285.

† *American Geologist*, vol. xii, pp. 43, 290.

‡ See article on "Scientific Volapuk," *Natural Science*, vol. iv, p. 55.

facts on which the conclusions were based. Hence minute particulars of work, and even many new terms may be needful to the progress of science.

This increase of knowledge, and its attendant complexities, render it more and more difficult for those whose time is largely occupied in other matters to devote themselves to special lines of research. To do so they must labour long and qualify by special training for each particular kind of work; and those only who can give up their whole time to one or other branch of the subject, whether of petrology or palæontology, can hope to do much work of permanent value.

This aspect of the subject need not dishearten anyone from giving attention to Geology, nor quench the hope that some service may be rendered. I trust that Geology will never lose its recreative aspect; that it will never cease even to be an interesting hobby to many a toiler in town and country. There are some, I know, who think that science loses in dignity if it is ever cultivated as a hobby. Personally I should scout such a notion; because, however humbly it be studied, if it confers one particle of happiness on any individual, it answers a noble purpose.

There is, however, plenty of useful work that can be done by those unable to follow in detail one limited branch of the subject. Nor must it be forgotten that outside his particular groove the specialist is on a par with others who seek to gain a general knowledge of geological work and progress. The science might advance if specialists only paid heed to it, but it would not thrive without the help and encouragement of the many who take interest in their results; and the number of these, I think, increases rather than diminishes. The attendance at our evening meetings and excursions testifies to this, for we are associated together not merely for the purpose of adding to the stock of knowledge, but for the equally important purpose of learning and profiting by what is known.

That Geology attracts so large a number of devotees is not surprising when we consider its aims, and the deep interest that must be aroused in "the story of our planet." It takes us back into such distant times, it reveals such changes in scene and climate and inhabitant. It tells of the building up of continent, the sculpture of mountain and vale; and generally helps us to realise the influence of the past on the present features and forms of life. It lends a charm to every country walk, gives an interest to the Fenland, and adds to our enjoyment as we tread the stony path of Glen Sligachan on our way to the mountains of Skye. That the records of our rocks enable us to picture scenes that are to some extent illustrated at the present day in every region of the earth's surface, is in itself a source of wonder and satisfaction, for in this country we can pursue our thoughts and observations in comfort unknown to the traveller in the Polar regions or on the Dark Continent. How great, then, our indebtedness to those who, like our Associate, Dr. Gregory, go out into the wilderness, and regardless of personal comfort and danger, bring to our minds the scenes they have visited, and who carry home stores of information with regard to geology and natural science in general.

Our present knowledge is the sum and substance of the notes and queries of all races throughout the period of their existence; but although science may be said to be coexistent with the history of mankind, and the observation of facts to have commenced at the earliest date, yet the geologist cannot live by facts alone, and the scientific interpretation of them hardly commenced before the closing years of last century, and did not flourish until Lyell had fully established the "Principles." His philosophic conclusions were, however, based on the systematic record of facts, the good fruits of which had been so clearly demonstrated by William Smith; and we, who now benefit by the accumulated knowledge, must still seek our earliest lessons in the field. We begin life, it is true, knowing nothing, but, thanks to our predecessors, we can acquire a great amount of information and even become intellectually specialised in a comparatively short period of time.

Most of us have been collectors; and that is one of the earliest stages of development through which the geologist passes. In time the general collection, which is most instructive, must be relinquished for more special collecting if we desire to aid the progress of science; but in all cases, as remarked by Sir Henry Holland, the interest "is one which augments with its gratification, is never exhausted by completion, and often survives when the more tumultuous business or enjoyments of life have passed away."*

Some of the early collectors did not outgrow the cumulative stage—notably the founder of the Woodwardian Museum at Cambridge, John Woodward, M.D., whose chief work, *An Attempt Towards a Natural History of the Fossils of England*, was printed in 1729, after the author's death. The publisher, in his somewhat laudatory introduction to the reader, remarked, in reference to the author's labours in collecting: "He succeeded indeed, but it was not without having carried it on for a Course of near Forty Years, with a Passion for the Improvement of Natural Knowledge in general, and with a particular View to evince the Universality of the Deluge." He did one thing, at any rate, which we may imitate with advantage, and for which Sedgwick gave him credit: he carefully recorded the locality from which every specimen in his *omnium gatherum* had been obtained.† Geology in those early days, and for long, remained in a somewhat stationary

* *Recollections of Past Life*, 1872, p. 53.
† *Geol. Mag.*, 1867, p. 44.

condition, although the process of collecting attracted many a learned man. They studied science in a fashion more deliberate than is the custom now-a-days. Thus James Parkinson, who was a busy medical man, living in the rural suburb of Hoxton, tells us, in 1804, that, "Impelled by that eager curiosity which a view of the remains of a former world must excite in every inquisitive mind," he "long and earnestly sought for information respecting these wonderful substances, from every source to which he could obtain access." Recognising the importance of cultivating "a taste for truly rational pleasures," he always allotted a small portion of his time to scientific pursuits. In due course, and after he had acquired a "little fortune," he "quitted the busy part of the world for ever," and published three volumes on the *Organic Remains of a Former World*, being "An Examination of the Mineralized Remains of the Vegetables and Animals of the Antediluvian World; generally termed Extraneous Fossils." In this work the epistolary form is adopted, and the first letter, though addressed to the author, is one which evidently narrates his own experiences. As it gives same notion of the early method of studying Geology in the field, I may quote his remarks. He says:

"In pursuance of a plan, on which I had long determined, of visiting the most interesting parts of this island, I quitted London last week with my daughter, accompanied by our old friend, WILTON, whose lively manners, as you well know, render him an excellent companion. . . . Our first day's journey was not completed before I discovered that the little knowledge which I had obtained was insufficient to enable me to form even a conjecture respecting the origin of the very first object which particularly engaged our attention. We were within about ten or twelve miles of Oxford, when WILTON, looking out of the window of the chaise, exclaimed: 'Well, I never saw roads mended with such materials as these before!' This, of course, drew my attention to the same object, which had so strongly engaged his; and I am confident that the astonishment excited in my mind was but little, if at all, less than that which possessed our friend, when I beheld a labouring man breaking to pieces with a large hammer a stone nearly circular, half as large as the fore-wheel of our chaise, and bearing the exact form of a serpent closely coiled up. Curiosity prompted me to stop the chaise, and to ask the man the name of the stone, and where it came from. 'This stone, sir,' says he, 'is a snake stone, and comes from a pit in yonder field, where there are thousands of them.' We all alighted, and with surprise examined same of the same species of stones, which he had not yet broken; and which, though evidently bearing the form of some strange animal, were undoubtedly formed entirely of stone. As we sauntered along, the chaise following us, we came to a neat, though a small, house on the roadside, which a sign, stuck in the hedge on the opposite side of the road, taught us was a house of public entertainment. Hoping to gain some further information respecting that which had so strongly attracted our notice, we entered this, literally, hedge ale-house."

There they are shown fairies' nightcaps, bones of giants, thunderbolts, and other curiosities, concerning which the travellers find themselves totally ignorant. An appeal is therefore made for information, and in the succeeding letters Parkinson proceeds to comply with the request.

A very great deal has been learnt since that was written, and the information obtained is usually given in a more condensed form; but I hope it will be long before such journeys of discovery are abandoned, even in this country. For many who may be stirred up to take an interest in geological research must be content to gather what information they can. They must not be discouraged, for even a little knowledge is never a dangerous thing, if they do not publish their observations.

Among those whom one meets in the field none is more deserving of sympathy than the self-educated local collector or quarryman who strives to learn what he can of Geology. Such men often render a service to science that passes unnoticed. Interesting and touching are many incidents in the *Life of an Artisan*, Joseph Gutteridge, ribbon weaver, of Coventry; but, as he truly remarks (p. 214): "A working-man is, by force of circumstances, precluded from studying geology in a scientific manner. To study the science properly, a man must have time and means at his command, and education as well as a natural inclination"; or, as Ruskin puts it: "We must endeavour to *do*, not what is absolutely best, but what is easily within our power and adapted to our temper and condition."* *The Life of Robert Dick, Baker, of Thurso,* shows how much good a man may do in searching for the fossil treasures in his neighbourhood; how keen his interest may become; and yet how impossible it may be for him, with limited scientific knowledge, to decipher the facts he has himself discovered.

There are others not lacking in education to whom we are largely indebted for our knowledge of the fossils of particular formations. Of David Homfray, of Portmadoc, it has been remarked that "It is seldom that we meet with a geologist who has toiled so hard, and amassed such a store of valuable information, but has never published an article on his favourite subject." That in itself is not necessarily a merit. He, however, did not conceal his light. "He was content with supplying information to others, which he always did most readily" †; and Sedgwick, Salter, Ramsay, and Hicks have made known his discoveries, which lay principally among the fossils of the Tremadoc Rocks.

In almost every part of the country the student can begin work by collecting some fossils within a day's journey of his home. If he finds nothing new, there is no reason why interest should thereby be damped. To gain information is in itself a pleasure and a service; but in the course of time puzzles are sure to arise, for there is much yet to be learnt, and in almost every locality there is need of collecting, with particular reference to the horizon as well as the locality of each specimen; need, also, for the gathering together

* *The Eagle's Nest*, ed. 2, 1891, p. 99.

† G. J. Williams, *Geol. Mag.*, 1893, p. 479.

of many examples of each species from the same and from different localities.

New specimens may always be found, even in formations so well searched as the Norwich Crag or the Inferior Oolite. In our excursions of last year Mr. Hinton obtained at Bramerton a form of deer not before recorded from the Norwich Crag, and Mr. Monckton added a species of crustacean, *Eryma elegans*, to the list of Dundry fossils *

Edward Forbes, writing in 1849, remarked that "The geology of England may be 'done' by the old fellows, but it is not overdone yet." He was then in Dorsetshire "working over every section of the Purbecks in the district, creeping over the beds with glass at eye, looking to the minutest traces of life, and its changes, in those curious fresh-water strata."† Forbes' work among the Purbeck Beds has continued to be our chief source of knowledge to the present day, though the subsequent discovery of Mammalian remains, and of other important fossils, have supplemented the knowledge. Nevertheless the geology of that well-known area, the Isle of Purbeck, had by no means been exhausted, as shown by the results of the recent six-inch survey by Mr. Strahan. Researches among the Highlands have lent their aid to the interpretation of the phenomena. By detailed mapping of the strata from Ballard Down to Upwey and Abbotsbury, Mr. Strahan has been able clearly to discriminate between the faults and foldings that occurred prior to the Upper Cretaceous period, and those that accompanied the great Isle of Wight disturbance; and he has proved the existence of great over-thrust faults.‡ I mention these matters to show that there is much to be done in areas that have been the most studied, and the fact was exemplified in the new and enlarged survey of the Isle of Wight; and yet after the completion of that work, our energetic Excursion Secretary, Mr. Leighton, proceeds to Sandown Bay, and finds in the Lower Greensand a fossiliferous horizon that had not been previously determined.§

The Wealden area again has been much studied and written about; but it has been reserved for our Associate, Mr. Lewis Abbott, to make a very remarkable discovery near Ightham. There, from fissures in the Kentish Rag, he has brought to light remains, not only of the Mammoth, Rhinoceros, and Bear; but of numerous small Mammals, some of Arctic species, others being Voles, Bats, Birds, and Frogs, identical with forms living in the neighbourhood.|| Even in a region so geologically unpromising as that of Hendon, Dr. Hicks has found much to occupy himself; and by his labours he has invested the locality with an

* *Proc. Geol. Assoc.*, vol. xiii, pp. 56, 131 and 210.

† *Memoir of Edward Forbes*, by G. Wilson and A. Geikie, 1861, p. 461.

‡ See Report of the Director-General of the Geological Survey for 1892. (Science and Art Department).

§ *Proc. Geol. Assoc.*, vol. xiii, p. 188.

|| *Proc. Geol. Assoc.*, vol. xiii, p 157; *Quart. Journ. Geol. Soc.*, vol. l, pp. 171, 188.

interest it did not before possess. Again, he has done signal service by finding organic remains in the so-called "unfossiliferous" Morte Slates of North Devon.

The Highlands of Scotland may afford a poor hunting-ground for fossils, but the discovery of *Olenellus* in the Cambrian Slates of Ross-shire, shows that grand discoveries are to be made. Our enthusiasm in the apparently barren district of Cornwall has been quickened by the researches of Mr. Teall and Mr. Howard Fox, who have made known its Radiolarian Cherts. The earlier discovery of Pliocene Beds at St. Erth was again one of singular interest, and taken in conjunction with that of the *Elephas meridionalis* at Dewlish, and of the isolated patches of Crag on the North Downs, it greatly extends our knowledge of the former extent of the Pliocene Beds; and bids us exercise the greatest caution in theorizing about the original extent of formations, when our information is based on negative evidence. Another remarkable discovery is that of certain Mollusca in the Upper Keuper Sandstones of Warwickshire, lately made known by Mr. Bullen Newton.* The finding of any traces of such organisms is a noteworthy fact in those ordinarily barren deposits.

Therefore, alike in well-explored regions, and in regions whose rocks have been thought to be barren, there is yet, and always will be, work to be done, not only by collectors, but by others who devote themselves to questions of geological structure. Such work, however, demands assistance from various sources. While there is much that can be done in the field, yet a large part of modern research is carried on in the Museum and in the Laboratory.

The quarryman toiling at his work finds some curious bones, and directs the attention of the local geologist to the fact. The geologist sees the importance of the discovery. He acquires the bones, and eventually forwards them to the palæontologist. The progress of discovery is yet far from complete, and long and arduous labour may remain.

This is what happened in reference to the remarkable Reptiles of Elgin, obtained by the Rev. Dr. Gordon, and submitted to Mr. E. T. Newton. As he has told us, however, he did not receive the bones, but only the places where they had been, and these proved to be enough for him. I never saw specimens that looked less promising: huge blocks of tough sandstone containing irregular ferruginous cavities. No mason ever laboured harder to carve a figure out of stone than did Mr. Newton in following the ramifications of these cavities. In the end, by means of gutta-percha, he was enabled to build up, with absolute accuracy, those portions of the skeletons of the Elgin Reptiles which he has described and exhibited before the Royal Society and before this Association.

* *Geol. Mag.*, 1893, p. 557.

Thus, so far as work in the field is concerned, we are greatly indebted to the intelligent quarryman, as well as to the local geologist, who recognises the importance of remains that appear otherwise most unpromising. We must, however, leave the collector to the quiet enjoyment of his labours along cliff or in quarry, and pass on to consider briefly the work of those who seek to interpret the structure of the country.

No more instructive task for the student can be found than that of mapping the outcrops of our formations over a particular area. Such a task grows in interest, and with the six-inch ordnance maps it may be attempted by anyone who has made himself acquainted with the leading facts and principles of Geology. Written explanations, though useful, can never be full enough to teach the science and art of mapping: they must be learnt in the field. The history of geology is written in different dialects, and work in the field must differ considerably when we deal with rocks that are folded and altered, as compared with others but little disturbed. Again, where volcanic rocks enter largely into the structure, or where Glacial Drifts prevail, our methods may differ very considerably. The student must gather his experience as he goes, and not expect his path to be altogether smoothed or even indicated for him.

In early days men went into the field and learnt for themselves the methods of mapping. They commenced with what we should now call sketch-maps—admirable for their time, considering their scale and topography. Such were the maps of William Smith, who sometimes drew in his lines from the top of a coach; but when we remember that he was surveying all England, single-handed, or with the sole help in later years of his nephew, John Phillips, we can marvel only at the grand work he accomplished. So also with Macculloch in Scotland. Great progress was made in the early maps of De la Beche in Cornwall and Devon, but when we compare them with the later surveys of Ramsay, Jukes, and Selwyn in North Wales, and these again with the modern maps of the north-west highlands of Scotland, we see how the surveys have become more minute and accurate with increased knowledge, with better maps, and with more ample time.*

Referring to the Geological Survey Maps, M. Renard once remarked that he had "frequently experienced difficulty in finding any exposures of rock to prove the validity of the published boundary lines," and hence he "inferred that the drawing of those lines has sometimes been a purely hypothetical matter."† Of course it has. Were everything clear there would be no trouble in mapping, beyond identifying rocks and fixing points: and the interest of the work would flag. Nevertheless, in areas

* See also Sir A. Geikie, *Trans. Federated Inst. Mining Engineers*, vol. v, p. 142.
Science Conferences, 1876, p. 379.

that seem to afford no evidence to a casual visitor, there are many indications that can be followed by one who works steadily over a large tract of country, so that in the end the drawing of boundary-lines, even in obscure tracts, is seldom "purely hypothetical," but rather a matter of justifiable inference. There are probably few parts of the country that at first sight appear more difficult to interpret than the agricultural regions of the Eastern Counties; and it may take a month to learn the particular local evidence to be relied upon, and to get an inkling of the behaviour of its strangely contorted drifts.

In starting work in a region with which one is previously unacquainted, except in a general way from the writings of others, it may be interesting to commence in a thoroughly independent spirit. In this way, two years ago, I began work in the island of Raasay. Had my journey been one in search of the picturesque, I could not well have chosen a more delightful spot. On the island itself there was almost every type of scenery to be found in a tract that nowhere rises much above 1,400 feet.

There was woodland with birch and fir, and even beech, with pleasant pathways that recalled the walks near Abinger and Leith Hill. There were irregular tracts of moorland stretching away to the north of the island, covered with thick heather and peat, diversified here and there with crags and rocky gorges; while scattered over the surface of the ground were blocks of granophyre and white sandstone that had tumbled from the heights above, and mingled with these was an occasional ice-borne boulder of Torridon Sandstone. There were tarns here and there up to a height of a thousand feet, and many a small cascade along the deeply eroded channels of the burns. From the highest point, the rough basaltic crags of Dun Caan, there was a grand panorama of the volcanic mountains of Skye and the ancient peaks of Ross-shire.

The coast itself was bordered for the most part by cliffs, with little bays and headlands, and with rocks of varied hue. On the west the great sheets of granophyre descend to form low cliffs, and the white crusts of this rock are dazzling in the sun-light. Further to the south rises a more irregular mass of dark and pale green dolerite, approaching in character to gabbro, which rusts and decomposes into a kind of ochreous sand that is dug for mending paths. On the south the white sandstones of the Lower Oolite, and the dark shales of the Lower Lias rise from beneath cappings of granophyre, and the scene is diversified with cliffs of red sandstone. It was along this part of the coast that, commencing work, as I have said before, in an independent spirit, I began mapping portions of the Torridon Sandstone with the New Red Sandstone. I soon found out the mistake, for the apparent conformity was very local, and the older rock was seen in places to be folded in a remarkable manner. The evidence of local conformity in stratification was, however, instructive, for it called to mind the discussions on the relative ages of the Elgin Sandstones, where New Red Sandstone rests on Old Red Sandstone without any really marked evidence of a break.

Along the eastern side of the island the scene was a most striking one, for the cliffs rise in a great face to over 800 feet in places, and seem farther on to blend with the crag of Dun Caan, over 1,400 feet above sea-level. The main portion of the cliffs is formed of the white sandstones of the Lower Oolite, and huge masses have broken away and lie in hazardous positions on the talus or form little islets in the sea. Great portions of these cliffs are wholly inaccessible, and I began to wonder how I could proceed with the mapping; but in the end this was the easiest part of my work, for it consisted in drawing a series of boundary-lines for Lower Oolites, Upper and Middle Lias, roughly parallel with the coast. In one part there was a huge landslip that rivals that of Dowlands, near Lyme Regis. The great founder was produced by the slipping of the strata over the Lower Lias or Pabba Shales. The ground above, where these shales outcrop, and where they are overlaid by the Middle Lias, is full of treacherous rents—holes so deep that one might disappear in a moment, and the same is the case in the white sandstones near Dun Caan, and over the summit of Beinn-na-Leac. On that hill so wide and deep are these cracks that I could not cross, and had to descend and clamber up hill again farther on. Sir Archibald Geikie, in his *Scenery of Scotland*,* had remarked, in reference to these fissures, that they are "sometimes so treacherously concealed with long grass and fern that in a mist or in the dark a traveller might easily be lost in them." I had noted this passage before I reached Raasay, and consequently walked with circumspection; but I could not help thinking that were any volcanic eruptions now to take place in the neighbourhood, some of these wide cracks might be filled from above with ejected material.

The New Red Sandstone of Raasay, with its conglomeratic layers, forms cliffs in two areas that reminded me exactly of the red cliffs of South Devon; following in upward succession, with the intervention of a thin series that may represent the Rhætic formation, there were Blue Lias limestones and shales with some sandy bands, but on the whole much like the Lower Lias of the west of England, with *Gryphæa*-beds and *Ostrea*-beds to match. Higher up there were shales with ironstone-nodules and many fossils that indicated the superior beds of the Lower Lias, with the *Hippopodium ponderosum* as in Gloucestershire, with *Ammonites Jamesoni* and other familiar forms. Above were the calcareous sandstones of the Middle Lias, with at base the *Ammonites margaritatus*, and higher up *A. spinatus*, *Pecten*

* Edit. 2, p. 36.

æquivalvis, and other characteristic fossils; and eventually I found in the uppermost part a band of oolitic iron-ore, comparable with that of Cleveland.

There was no difficulty in marking in the boundaries of the main divisions of these strata on the coast; they could be traced in the deep channels of the burns, and subsequently followed across the hills through peat and heather, for the harder rocks occasionally protruded or left their impress on the contours. There was one area, however, that for many days gave me incessant trouble; it was less than a square mile in extent.

It was a broad glen, through which the principal stream cut deeply into the calcareous sandstones of the Middle Lias. It was bordered by clay slopes, partly covered with Peat and Boulder Clay, and farther away on each side by scarps of calcareous sandstone, the beds of which closely resembled those of the Middle Lias below, but yielded only a few Belemnites. There was evidence of faulting and evidence of land-slipping, where masses of strata had broken away from the scarps and subsided to lower levels; but at first I could not fit all the beds of calcareous sandstone into their proper stratigraphical position. It was in extending my work around this area that I came across the oolitic ironstone on top of the Middle Lias—it was a revelation. It occurred in the banks of a small burn that flowed along a dip slope, and joined the main stream at right angles. I thought to myself if I find shales and Upper Lias fossils I shall be saved further anxiety. I went straightway to the main stream and found a low cliff partially concealed by vegetation; but in the bank and in the bed of the stream there were black shales, and after splitting up many slabs I was rewarded by finding "Serpentine Ammonites." Great was my joy. Nor did I care for the moment whether the species was the true *Ammonites serpentinus* or *A. falcifer*—it was enough to find definite Upper Lias forms.

Proceeding with my work, I found that wherever sections disclosed the junction, the calcareous sandstones of the Middle Lias were capped by this band of oolitic ironstone, some four or five feet thick; that above came the black shales of the Upper Lias; and these were succeeded by another set of calcareous sandstones, that eventually yielded *Ammonites variabilis*, and formed the base of that great series of white sandstones which belong to the Lower Oolites. Knowing exactly where to look for them, I found that the ironstone and the Upper Lias shales could be tracked to places where they had been hollowed out in ravines by cascades, and where the tumbled blocks almost concealed their presence. Thus, by means of fossils and the stratigraphical succession of the several types of rock, order was established, and I had no further geological anxieties.

Over great part of the island the main rock-divisions could indeed be mapped without reference to fossils; but without the organic remains no true comparisons could be made with the strata of other areas, while here and there, in obscure and faulted tracts, no definite solution of the structure could have been gained, had not the fossils given their testimony. What surprised me most was the great general similarity in the lithology of the strata on Raasay—from the New Red Series to the base of the Lower Oolites—and that of equivalent strata in the west of England and Yorkshire. The lithological changes, too, in the successive beds corresponded well with the palæontological divisions in each area.

Those who have been engaged in the pleasant task of geological mapping know well the value of lithological characters. R. D. Irving has spoken strongly on this subject. He says the value of this evidence "in tracing formations from point to point can hardly be over-estimated, being as great as that of palæontological evidence, and in his judgment of much the same nature."* I quite agree with him. Otherwise, how is it that those who have worked out the stratigraphy and zones of a certain district, go elsewhere and prophesy correctly that certain fossils will be found in certain strata of peculiar lithological type and position?

In visiting only occasional sections, especially in obscure and faulted tracts, one may easily be led astray by lithological characters; but experience teaches where caution is necessary. One might visit a quarry at Upwey, near Weymouth, and fancy that the white, chalky limestone with flints was a part of the great Chalk formation; but the presence of *Pecten lamellosus* and other fossils would reveal the fact that the chalky rock belonged to the Portland formation. Where Gault clay rests on Oxford or Kimeridge Clay, where Lower Greensand rests on Portland Sand, and in many other instances, lithology may be a quite untrustworthy guide, especially if we commence work in such a district.

Take, however, the Rhætic formation of Somerset, based on the variegated marls of the Keuper, with the debatable beds of grey marl on top, then the black *Avicula-contorta* shales, and the distinctive Landscape Marble and the White Lias above—we might map the formation by means of these stratigraphical characters throughout the country, from Bath to the Mendip Hills, without reference to a single fossil—if we found the above-mentioned sequence. On the other hand, the presence of black shales alone in a faulted tract would give no clue—for they might be Carboniferous, or Lower Lias, or Upper Lias—until an *Avicula contorta* or other fossils were found.

Thus it is that the field-geologist must know the characteristic fossils of the formations with which he is dealing.

To do this nowadays may seem almost a superhuman task. Some palæontologists may tell you that field identifications are

* Seventh Ann. Rep. U. S. Geol. Survey, 1888, p. 378.

useless; and no wonder, considering the stumbling blocks that strew the path of the student of organic remains. Who, for instance, but the specialist dare put a modern specific name to an Ammonite or a Brachiopod, for their names are legion and their synonyms are every day increasing. Those, on the other hand, who have had great experience in the field, will tell you that you must be able to identify your leading and characteristic fossils on the ground. With this I entirely agree. One must learn, however, by experience, and after collecting many specimens in the field, their forms become impressed on the mind, and the names once learnt are not often forgotten. In this way one may be able to recognise the common and characteristic fossils of the formations, including the forms that distinguish the principal zones. With the differences that constitute minor zones one need not be at all concerned, for such work can only be undertaken by those who can give unlimited time to individual sections. A recent paper by Mr. S. S. Buckman, a work of infinite labour and pains, shows how far the particular collecting of fossils can locally be carried. By him zones are sub-divided into "hemeræ," characterised by particular modifications of Ammonites. No one, however, can speak personally about such minute work, without devoting many months to quarrying in every exposure described, so as to follow each layer over many hundred square yards*; nor without mastering all the intricacies of modern doctrines about Ammonites. Here the brief period of our existence puts a limit to possibilities.

For this detailed study of the succession of organic remains, the worker naturally requires a much more minute division of species than is necessary for the one engaged in tracing formations over a large area; and here great difficulties and misunderstandings arise. The one is mainly interested in the evolution of species, in what Mr. Hudleston terms "pedigree-palæontology"; the other has no special concern in the matter, beyond being interested in the general results.

It seems to me that some compromise is absolutely necessary. The zoology of past ages is not the sole aim of geological investigation. Nor would geology progress if each worker kept entirely to his own groove, and gave his results in a form unintelligible to others, who are working at branches of the same subject. Chemical analyses, microscopic sections of rocks, details of quarry-sections, are all useful in their way, as are the descriptions of species and mutations; but they are useful to a limited number of individuals. Details of the strata are of the greatest service to the field-geologist, but he groups them according to their stratigraphical characters into different formations, after the method initiated by William Smith.

If specific names are so multiplied that only the specialist in

* On this subject see remarks by Edward Forbes, *Literary Papers*, 1855, p. 40

each group of organic remains can deal with them, they become, of course, of no service to the field-geologist; and a kind of zoologico-geological anarchy will come to pass.

I am, however, of a sanguine disposition, and believe that the only revolution that is wanted is in palæontological nomenclature. For my own particular work I require only to know the names of the leading fossils that characterise the larger stages into which our formations are divided. In the Inferior Oolite, for instance, the Upper and Lower Divisions adopted by Mr. Hudleston are palæontologically sufficient—those divisions being characterised broadly speaking by *Ammonites Parkinsoni* and *A. Murchisonæ*. There is an intermediate stage with *A. humphriesianus*, locally developed, which serves to connect the two. If I venture to name an Ammonite *A. Parkinsoni* I do so in the broad and general sense in which the name was introduced. I have no occasion even to employ the sub-generic names of *Cosmoceras* or *Parkinsonia*, because I find such names are not only troublesome to remember, but they are in a most unstable and lamentable condition. Very generally two, and often three, synonyms of these sub-generic names are to be met with in different works. The student who pays attention to the literature of the subject is obliged to learn and translate some of these many names before he can learn the facts, and know that an *Olcostephanus* and a *Simbirskites* may be applied to the same species of Ammonite. The amount of time one may lose in ascertaining the nature of a fossil from its name thus becomes every day more and more distressing. This might easily be avoided if all specialists would have the consideration of putting the sub-generic names in brackets after the familiar generic name. This is not much to ask; and I am happy to say it is adopted by some of our highest authorities, by Mr. Hudleston, Mr. E. Wilson, and Mr. J. F. Walker.* Thus *Mathilda* is a sub-genus of *Turritella*, and Mr. Hudleston puts *Mathilda* into brackets.†

There is an Oyster which, when I first went into the field, was known as *Ostrea Marshi*, it proved to be a synonym of *Ostrea flabelloides*, and that name came generally to be introduced. Since then the genus has been sub-divided, and the Oyster is by some put down as *Alectryonia flabelloides*, and by others as a *Lopha*, they call it *Lopha flabelloides*. Those who can give their whole time to Oysters may assess these names at their proper value. The geologist must adhere to the *Ostrea*, and, if need be, put the *Alectryonia* or the *Lopha* into brackets. Anyone can recognise an Oyster, but to identify a *Lopha* requires some particular knowledge of the world.

In the meanwhile, I am not without authority in naming my

* Hudleston and Wilson, "Catalogue of British Jurassic Gasteropoda"; Walker, *Geol. Mag.*, 1892, pp. 438, 440, etc.

† Hudleston, "Gasteropoda of Inferior Oolite," p. 230; see also his remarks on "Nomenclature," p. 5.

fossil "*Ammonites Parkinsoni*," or "*A. Sowerbyi*," as the case may be; for those to whom we look as palæontological fathers are equally at a loss. They cannot deal with the very numerous mutations into which these old species are sometimes divided. They write down a "Parkinsoni Ammonite," or a "Sowerbyi Ammonite," in inverted commas, or speak of a fossil as "near to," or "allied to," or "conforming to," or "approaching" such and such a species; for they, too, outside their particular province, find the identification of species becomes less and less certain the more they are split up. Indeed, their value in stratigraphical geology may be said to have decreased in proportion to the over-production of names.

I know very well that to interfere with another's business is not altogether prudent; but I have no desire to do that. I have no wish to be lost on the shifting sands of palæontological nomenclature. I only wish that the labours of all should tend to the common weal; that they should be intelligible and useful to their fellow labourers, not necessarily to the world at large.

We must remember that our rocks are not to be regarded simply as cemeteries, where, with Hervey, we meditate among the tombs. The succession and relations of the rock-masses, their method of formation, and general natural history, their influence on the scenery of the present day, are matters of the greatest interest to the Geologist.*

In the study of these subjects all workers may lend their aid and work in harmony. For my own part, I believe there are few serious differences with regard to general principles and matters of fact. The differences are mainly those of methods of tabulating facts or indexing knowledge.

Our geological formations, for instance, do not escape a certain amount of quite unnecessary abuse, because, as everyone knows, they do not represent precise periods of time. Those who have been engaged in field-work know full well that each country must have its stratigraphical divisions—they vary even in this country from place to place. In themselves, they are records of certain physical conditions, however local, and it is only by their careful delineation on maps that the physical structure of countries can be determined. Purely palæontological divisions can never be satisfactorily made in the field over extensive tracts of ground: the absence or rarity of fossils in so many places would alone be a bar; nor, if such divisions could be followed, would they be of service in illustrating the stony structure of the land. On the other hand, as zones or groups of zones, the palæontological divisions are invaluable, not only as indicating the sequence of organic remains, but in correlating in a general way the formations of distant areas.

Hence, while in our own country and in other lands we must

* See Henry Woodward, Address Geol. Section, Brit. Assoc., Manchester, 1887.

in the field always adhere to the local stratigraphical divisions, it is desirable to have general terms to indicate approximate epochs or periods of time.* This subject was but lately brought before us in a philosophical essay by Dr. W. F. Hume. He made "zones" most interesting; and showed the need, when we compare the varied deposits of one period, of general terms that express age, rather than stratigraphical characters.

In the field our interest is naturally centred in certain rocks or formations, but while British Geology, like the history of the British Empire, must always be one of our chief studies, subjects of world-wide interest arise in connection. Many of the wider questions of the natural history of successive periods, of old sea-basins, and physical changes, are not, however, to be determined by anyone singly in the field; they belong to the arm-chair of the geological veteran who can philosophise from the accumulated observations of others.†

THE WORK OF WOMEN.

Science in general has probably throughout time been cultivated by women, but only during the past ten years has Geology in particular been taken up by them as a serious study.

Their influence, however, has been felt in one way or another by most geologists, notably by Lyell, Mantell, and Murchison. It was very largely due to Lady Murchison that her husband was induced to exchange the "noble science" of fox-hunting for the no less invigorating science of field-geology. It is, moreover, a remarkable fact, and one which caused some amusement to his friends, that soon after the crop had been exchanged for the hammer, Murchison, who was exploring the quarries of Oeningen, learnt that "a very remarkable new quadruped had been recently exhumed." Cuvier thought, from a drawing sent to him, that "it was in all probability a fox." This was enough for Murchison. He set out in pursuit, acquired the animal, and gave it to the British Museum.‡

One of the earlier students of Geology during the present century was Miss Etheldred Benett, of Norton House, near Warminster. To her we are indebted for our first particular knowledge of the fossils of the Chalk and Upper Greensand of Wiltshire.§

I need only mention the important discoveries made by Mary Anning at Lyme Regis, as attention was particularly drawn

* See Paper by H. S. Williams, *Chicago Journal of Geology*, vol. i, p. 180. Teall, Address to Geol. Section, Brit. Assoc., Nottingham, 1893.

† See Prof. Lapworth's Address to Geol. Section, Brit. Assoc., Edinburgh, 1892.

‡ See Geikie's *Life of Murchison*, vol. i, pp. 93, 154, 155.

§ She contributed to Sir R. Colt Hoare's *County History*, "A Catalogue of the Organic Remains of the County of Wilts," with illustrations, and to the accuracy of her drawings of the famous fossil sponges of Warminster Dr. Hinde has testified. Separate copies of this work (dated 1831) were privately distributed.

to them on our excursion to that locality.* I propose to refer mainly to the work of women published by the Geological Society of London.

As early as 1823, Mrs. Maria Graham communicated to that Society "An Account of some Effects of the late Earthquakes in Chili" †; but a long interval elapsed before we again find any article from a lady in the Society's publications. Then in 1862 Miss E. Hodgson, of Ulverston, gave a particular account of a deposit containing Diatomaceæ, etc., that she had discovered in one of the iron-mines near her home.

A quarter of a century passed before others came to the front, and now the work of women occupies a prominent place in the Journal of the Society. Since 1887 our Vice-President, Miss C. A. Raisin, has published her observations on the Metamorphic rocks near Salcombe, in South Devon, the results of studies carried on both in the field and under the microscope. These led her to maintain that there is no evidence of progressive metamorphism between the Devonian slaty series and the schists or highly altered rocks of the district. She has laboured again among the Volcanic rocks of the Lleyn promontory in North Wales; among ashy and slaty beds which yield evidence of Bala fossils; among old lava-flows and rocks with spherulites, amygdaloids, and agate-nodules, some of which suggest the former presence of geysers. She has dealt with the disputed base of the Cambrian Series in Caernarvonshire, and shown by detailed observation in the field that it is clearly marked by a series of conglomerates and grits, and that the Llyn Padarn felsite is Pre-Cambrian. She has also made known her interesting discovery in the same region of Variolite, which is a kind of spherulitic structure that occurs at the margins of certain masses of basic igneous rock.

Miss M. J. Gardiner, in 1888, gave results of a microscopical study of the greensand-bed at the base of the Thanet Sand. This bed, in addition to other mineral ingredients, was shown to contain in places as much as twenty per cent. of flint; a fact of considerable interest, as but little or no flint is recognised in modern beach-sands that fringe our Chalk cliffs.

Two years later, Miss Gardiner brought forward the results of her observations on Contact-Alteration near New Galloway. These were the outcome of a considerable amount of field-work, and of subsequent microscopic investigation. The facts related to Silurian rocks that were altered by contact with granite, probably accompanied by the action of highly heated water; but there was a certain amount of minute folding in the rocks that may have accompanied the injection of the granite.

* *Proc. Geol. Assoc.*, vol. xi, p. xxviii.

† *Trans. Geol. Soc.*, ser. 2, vol. i, p. 413; Lyell, *Principles of Geology*, vol. i, ed. 2, p. 460.

The subject of Palæontology has not been neglected. Miss J. Donald, of Stanwix, near Carlisle, has given her attention to the Carboniferous Gasteropoda, not only studying the fossils from the rocks in the north-west of England, but the various types and choice specimens in Museums in this country and on the Continent. Some results of her studies and the descriptions of new species were published in 1887 and 1889.

In 1890, Miss Coignou described a new species of *Cyphaspis*, a Trilobite from the Carboniferous Rocks of Yorkshire.

In 1892, Miss M. M. Ogilvie, D.Sc., communicated the results of work done during two seasons in Southern Tyrol, in the celebrated Dolomite region of the Alpine Trias. Mapping out the several sub-divisions of the Triassic strata, on a scale of about three inches to a mile, and gathering fossils from the different zones, the authoress was enabled to interpret the structure of a complicated and faulted area, in places 8,000 to 10,000 feet in elevation, and to determine the relative ages of the fossiliferous groups about which previously there had been much confusion. Beds of Dolomite, that occur in more or less isolated mountain-masses, had been explained as altered Coral-reefs; but the observations now brought forward by the authoress led her to conclude that while there were several horizons of Dolomite, and coral-remains occur in them, yet their peculiar features were in the main due to earth-movements and denudation, and the theory of isolated reefs must be abandoned, for that of normal sea-deposits. Miss Ogilvie has subsequently described more particularly the local and lenticular masses of coral-limestone.*

If, however, I were to attempt to recount all the doings and sayings of our lady geologists, I should require not one evening, but many days. I might refer to the studies of Miss Agnes Crane among the Brachiopoda; to those of Miss Charlotte Eyton in North Wales and Shropshire. I might venture abroad and speak of the researches of Madame Pavlow.

I have no desire unduly to exalt the work accomplished by women, but in giving a brief account of the papers which they have read, or rather which others have read for them, before the Geological Society of London, I was desirous of showing that they have dealt with all branches of the subject. If there was one part of it that I should have thought was unsuitable, it would have been that of geological mapping. Even in England in the process of a field-survey one must spend many hours of a long period of time in spots the most lonely and desert. At other times there may be visits to pits and quarries, to railway-cuttings or mines, where none but men—and not always polite men—are at work; and I remember on one occasion in an out-of-the-way quarry in Glamorganshire, encountering a number of miners engaged in the animated pastime of cock-fighting. Nevertheless

* *Geol. Mag.*, 1894, pp. 1, 49. See also *Review of Reviews*, Sept. 15th, 1893, p. 287.

while the greater part of one's time in mapping is spent in trespassing without leave, I have never met with any serious hindrance, and never with anything more objectionable than torrents of opprobrious language. In all cases of verbal opposition I have found that the deaf ear and the soft answer have effectually turned away wrath. Still I am disposed to think that the time has not yet come, that our civilisation has not attained that high standard, when lady geologists could join the Geological Survey and wander at will and unattended over the country, without danger of molestation. Nor do I personally like the idea of women toiling at such arduous work as that of geological mapping.

However, the fact remains that they are taking the highest positions among the men as original investigators, a fact shown not only by communications made to the Geological Society, by others sent to the Royal Soc ety, the Chemical Society, and elsewhere, but also by the high honours they are taking at the University of London. In the near future when women may be Professors at the Universities and the Colleges of Science, when some indeed may be actively engaged on the staff of the British Museum, then it is to be hoped that they will not become so wholly engrossed with their special work, as in the evenings to shut themselves up in their studies and neglect the other members of the household.

Geology in the Study.

There is perhaps no more important a subject than that of Geological Literature. It may be said that all of us owe more to the experience of others than to our own observations; we can learn more by reading than by personal research: but without observation we should have a very sorry idea of the subject. A week in the field may be worth six months in the study, and half an hour in a quarry may teach more than any chapter in a book. Nevertheless after our rambles in the field we come to the study with an interest awakened in the writings of those who have stored up such a vast amount of information in the Transactions of our Societies, in Magazines, and in Monographs.

Some, it is true, appear to be more keen in writing papers themselves than in reading those of other people: and their enthusiasm seems for the moment to be clouded if you ask, "Have you looked up the literature of the subject?" Yet they write, and probably expect some others to read their papers.

Ruskin has lamented that we "are still eager to add to our knowledge, rather than to use it; and every day more passionate in discovering,—more violent in competition,—are every day more cold in admiration, and more dull in reverence."*

* *The Eagle's Nest*, ed. 2, 1891, p. 87.

If this be true, it is not altogether as it should be; but Science cannot remain in a condition of stagnation, and our great aim must be to avoid choking it with superfluous matter: for those who write without regard to what others have done may cast unnecessary burdens on the literature.

The term Literature as applied to Geology may not altogether harmonise with that defined by Stopford Brooke to "mean the written thoughts and feelings of intelligent men and women arranged in a way that will give pleasure to the reader." Still those who do read *The Quarterly Journal* or *The Geological Magazine* may not wholly disagree: but when we apply the test that "pleasure is only given when the words are carefully or curiously or beautifully put together into sentences"; that it "arises, not only from the things said, but from the way in which they are said," we might perhaps hesitate to include many geological works under the heading of "Literature." It seems curious, now that almost every subject has its Literature, of one kind or another, that a journal like *The Athenæum* should profess to deal separately with Literature, Science, and the Fine Arts, placing works on Topography and Genealogy as Literature, and the Life of Darwin as Science.

I am disposed to agree with the definition of Robert Buchanan, and to regard as literature, in its truest sense, that work which is of permanent interest and value; for while regarding choice language as an ornament, we look first to the substance contained in the work. Few works on Science can be claimed as of service to students of British Literature in point of style, though the writings of Lyell, Whewell, Hugh Miller, and some few others are occasionally mentioned in books that deal with Literature in general.

British Museum Catalogues or Geological Survey Memoirs would not be included, nor could many other geological works be considered as readable in the ordinary acceptation of the term; for in Science we mostly want our information in a concentrated form.

Geology may, however, claim to have its history, its biography, its works of travel, its encyclopædias and dictionaries, its poetry, its philosophy, and even its fiction and romance.

I have already referred to some of the historical works. Among them I should include Hutton's *Theory of the Earth* and Playfair's *Illustrations*; Sowerby's *Mineral Conchology*; De la Beche's *Report on the Geology of Cornwall, Devon, and West Somerset*, and, of course, Lyell's *Principles*.

With regard to very early works on Geology, it has been said that all that was written previous to the present century might be blotted out of existence without serious loss. I do not quite share that view, for if we divest our science of the history of its development and progress, we lose much that is not only interesting, but sometimes valuable. I was pleased to see that in his *Notes on Dartmoor* General McMahon found occasion to quote the prophet Jeremiah in reference to the action of surface-heat on rocks.*

The *Itinerary* of Leland; the *Natural History of Oxfordshire*, by Plot (1677), and that of *Northamptonshire*, by Morton (1705); the *Observations* of Maton *in the Western Counties of England* (1794-96); and other works of the kind are of great interest to those who have examined the districts described; the facts are often most valuable, and many of these old topographical works contain accounts of quarries no longer worked, of ancient well-sinkings, and of the discoveries of fossils.

Perhaps our earliest text-book of Geology was that to which my attention was drawn by our secretary, Mr. Sherborn, by Erasmus Warren, entitled *Geologia; or a Discourse concerning the Earth before the Deluge* (4to, London, 1690). That is two hundred years ago, and the book, I must say (though I have not read it), may be looked upon simply as a curiosity.

As an instance, however, of the trials of authors and of the fact that history repeats itself, I may mention that in 1752 Da Costa published proposals for printing by subscription *A Natural History of Fossils*, but the assistance received was "far from supporting the expence." However, he issued his work in 1757, and used care "neither to multiply the species, nor lessen their number, unnecessarily." He "added to the description of each species the *synonyma of authors*"; and remarks, "As I have availed myself of the labours and discoveries of preceding writers, so they have been faithfully quoted: and, however I may differ from them in opinion, I have endeavoured to treat them with a becoming regard."

The labours of these early fathers have to be interpreted. This is the case also with the work of the old masters, in what Whewell termed the "heroic age" of Geology.† The classic essays of Sedgwick, Buckland, Conybeare, Fitton, De la Beche, Lonsdale, and others, have in a measure to be interpreted by the light of modern days, but their stratigraphical facts remain of permanent value; and those who know a district fairly well will find their memoirs most interesting and valuable. They wrote at leisure, and after long labour; there was not that haste for priority which mars many a good work now-a-days. Nevertheless, it has been truly observed that as time goes on, the labours of old observers are often summed up in "a few lines."

Here to some extent *Biography* comes to our aid, and to my mind it is always interesting to know something of the life, of the manner and opportunities of work, of those who have rendered service to science. Such information adds great interest

* *Quart. Journ. Geol. Soc.* vol. xlix, p. 394.
† *Proc. Geol. Soc.* vol. iii, p. 396.

to the study of their writings. The drawback may be that while men of mark are thus immortalised, there are numbers whose silent and yet effectual work has been lost sight of. We could not dispense with the memoirs of William Smith, of Murchison, Lyell, Sedgwick, Jukes, Edward Forbes, and others, for in them we have records, not only of their own achievements, but also of the doings of many of their contemporaries. The association of the geologists of old with many localities and formations, gives to these an interest far above that of districts that have never been described. This may sound very much like sentiment, but if we divest Science of all sentiment it would be left very dry indeed. Geology has its *Romances*, and I use the term in no disrespectful way, for I should include those works that restore in definite outlines the features of the land and water or the extinct monsters of the past. Like the *Waverley Novels*, they serve to bring vividly before us what may have happened in bygone times.

What most concerns us is our inability to read, or even to consult, more than a small fraction of the works that have been published; and yet our first duty is rather to ascertain what is known, than to seek to add to the accumulated knowledge. Here great sub-division of labour is requisite, and it becomes necessary that some individuals, at any rate, should devote themselves to reading the papers of others. This is generally regarded as drudgery. Few enjoy making abstracts, or even reading papers on subjects in which they are not specially concerned. Yet Science would make little, if any, progress if there were no Manuals, Monographs, Synopses, Catalogues, Records, and even Dictionaries of Terms, of which we sadly want a new one.

Our indebtedness to such volumes is not always cheerfully, but sometimes grudgingly, acknowledged. There are indeed some who have been known to rejoice at the overthrow of some Text-book definition or explanation. It is always satisfactory to correct an error, but surely it is a lamentable thing to find that others have gone astray, or that views long held in veneration are untenable. The satisfaction can only be in the elimination of error—not that we have been the accidental causes of the correction. In all respects it is far more satisfactory to find that those who have gone before us have been right.

One great work of the day, and of all times to come, must be the sorting and arranging and tabulating of the many facts gathered together in a more or less chaotic manner in the various publications devoted to Science; for, however much authors may disperse their separate copies, there can be no doubt that papers soon become buried up and lost sight of in the serials, by the accumulation of successive volumes. This great "talus heap of geological literature" is being continually abused, even by some who contribute to it. We must all, therefore, be indebted to those who sift out the golden grains, and rescue them from oblivion.

The work is essentially of two kinds; the one being simply the Record of papers, the other the Catalogues of Fossils, or Monographs on special subjects.

The great task of cataloguing our British Fossils, accomplished so thoroughly forty years ago by our old leader, Professor Morris, requires many a helping hand before such a work can represent the present state of knowledge. Geologists have welcomed, though by no means in a generous spirit, the Catalogue of British Fossil Vertebrata by Messrs. Smith Woodward and Sherborn, and that on British Jurassic Gasteropoda by Messrs. Hudleston and Wilson. To continue in other departments this most important work would furnish interesting, if laborious, occupation for the winter evenings of many geologists. They would not reap any pecuniary reward it is true, but they would earn the gratitude of future, if not of present, generations.

Three years ago our Secretary, Mr. Sherborn, commenced his *Index Generum et Specierum Animalium*, a work that aims to give references to all names of living and fossil animals. This is one of the most solid contributions to Science that has ever been attempted.

Work of this character, though not always appreciated as it should be, may require as much knowledge and judgment and care as original work. The old Catalogue of Morris has stood for forty years, and is most valuable now.

The work of recording the titles and contents of papers is a most complex and difficult matter.

Twenty years ago, the Editor of *The Geological Magazine* started a series of Brief Abstracts which were "intended to serve as the commencement of a 'Record of Geological and Palæontological Literature for 1873,' to embrace abstracts of all papers published abroad or in the provinces."* A number of short abstracts were published in *The Geological Magazine* for 1874; but it was soon apparent that sufficient space could not be given to this work in a magazine that could devote but a few pages each month. Hence an independent publication was organised by Mr. Whitaker, and started under the name of *The Geological Record*. Its career has been a chequered one. The first volume, for 1874, was published at the end of the following year. It was a work of 397 pages, it contained 2,130 entries, and the labour of making abstracts of papers was performed in an honorary way by twenty-eight Geologists. That the work was appreciated was shown by the fact that the number of subscribers was large enough to cover the actual cost of printing and publication; while the British Association subsequently voted a grant that prevented any serious loss with regard to the working expenses.

The yearly volumes became each year somewhat larger, and

* See *Geol. Mag.*, 1874, p. 72.

in 1878 there were 3,530 entries. The work, however, made its appearance later and later, so that the volume for 1879 appeared in 1887. Subscribers very naturally diminished in numbers. Mr. Whitaker, who for two years had been assisted in his editorial work by Mr. Dalton, retired—for residence away from London was a great drawback. Then Mr. Topley bravely took the helm, and in 1888-89, with the aid of our indefatigable Secretary, Mr. Sherborn, he brought the work up to 1884, by means of two volumes of titles only; but the vessel had gone too far out of its course, many of the original hands had deserted, and it is no wonder that after an ineffectual struggle for existence the enterprise was wrecked.

Records are of no use unless published with regularity. Indeed, it may be said that the Geologist who is anxious to write a paper cannot wait even a year to learn from a Geological Record whether or not his or her facts are new. To trust to an Annual Record is not the way to be "up to date"—and if one waits a year or more, one will then be a year or more behind-hand. The value of annual records is to enable the worker to ascertain the past literature: they do not and never can serve for the immediate present.

There is no doubt that all workers have to make their own bibliographical lists. No one wants a complete record; and therefore local or selected lists of works may be more really useful than big annual volumes that aim at including everything published all over the world.

Personally, I have found the county-lists of Geological papers, compiled by Mr. Whitaker, of greater value than any Geological Record. Topographical lists, however, do not furnish the information required by workers on Eruptive rocks. Others want papers only on certain formations, or on particular groups of organic remains. It is not possible to please everyone. Hence, we come back to the full general record; and as regards that we remain in a very unsatisfactory state.

The Geological Society of London has for many years rendered the greatest service by listing the titles of all geological papers that appear in the serials added to their library. The number of periodicals is ever on the increase, and it seems to me impossible for workers in any one country to perform fully the task of recording papers published all over the world. Acknowledged incompleteness is fatal. We must aim in all things at perfection, although we know it cannot be attained. In any attempt at a complete record, the division of work must be dealt with internationally. At the present day the waste of labour by repetition in records published in different coutries is great and serious. The repetitions that must occur in records devoted to different branches of science, from the overlapping and dove-tailing of subjects, can hardly be avoided.

So far, then, as each branch of science is concerned, I think we must have local records. Inasmuch as papers on Foreign Geology are published in this country, and papers on British Geology are published abroad, the complete record of works could only be given in an International Record of Scientific Literature—and that is not likely to see the light of day, until peace and good will prevail amongst the nations.

Five years ago, however, Prof. Blake started on a Record by himself; and in his *Annals of British Geology* he has for three years given to the world an admirable summary of the work done in this country. He has essayed, and not without success, to make the work in a measure readable and instructive. He has tried to give so much of the material of the papers, that we need not have to go to the originals to extract the substance they may possess. In this way he has made his work invaluable to the provincial worker, who has no ready access to a good library. Many papers doubtless are published that have no permanent value, though they may serve a useful local purpose in arousing interest in Geology. To know whether or not a paper contains original information is a great service; but when we think of one man reading, and to a certain extent criticising 700 papers and memoirs, we can but be amazed at the amount of time and pains that Prof. Blake has bestowed upon his work. That he has not himself escaped criticism would probably surprise no one less than himself; but that he has rendered a noble service no one will deny. Doubtless he has in some cases attempted more than is desirable. No worker can justly or safely quote second-hand; and to give, at length, lists and catalogues of fossils seems to me not only unnecessary, but, by adding to the cost of the volume, a possible hindrance to success. So long as Prof. Blake gives us all we want it may seem unkind to complain if he gives more; but it is very distressing to think that his labours have so far been attended with loss.

Thus, whether we contemplate the subject in the field or in the study, we find Geology to be a "story without an end." Our chief aim is the record of facts and their interpretation: our chief reward is in the work itself—but that reward would be a somewhat barren one if it ended in the purely intellectual occupation, if our hearts were not warmed with some glow of enthusiasm in the contemplation of the results so far achieved. This I think is the true *Poetry* of Geology.

I did find at a bookstall a little book entitled *Geology: a Poem in Seven Books*, by the Rev. John Selby Watson—one of Pickering's publications, beautifully printed, and dedicated to Lyell; but I could not read a page of it. The Poetry of Geology is best dealt with on the summit of Dun Caan—or in prose in such works as Shairp's *Poetic Interpretation of Nature*, or Geikie's *Scenery of Scotland*. Poetry leads on to the last subject to which would briefly refer. Books have been published on the *Philosophy* of Geology by Jobert and by Page—but they simply give outlines of the leading teachings of Geology. The true philosophy seems to me to be the ultimate good we derive from the study. This is not always apparent when we witness the occasional "Quarrels of Authors," and find that sympathy and even generosity are occasionally stifled in the struggle for scientific existence. Here to a certain extent Philosophy comes to our aid, and although each one doubtless has a philosophy of his own, we look to the future to set matters straight. In the meanwhile it is interesting to read the remarkable, though somewhat diffuse, work by Ernest Renan, published in 1891, and entitled *The Future of Science: Ideas of 1848.* He took the highest ideal of Science, not only as "a system whereby to explain things," but as a sort of embodiment of truth, with the philosophy of which the highest interests of mankind were bound up. At the same time he fully recognised the importance of careful detailed work; and some of his remarks seem so appropriate that I venture to conclude with a quotation. He says:

"When we reflect upon the enormous amount of intellectual work and activity that has been engulphed for the last three centuries and even in our days in the periodical publications," yet we may feel happy that "All this expenditure of intellectual force is not lost, providing these controversies have contributed one single atom to the fabric of modern tnought."

"Hence the true interests of Science demand more than ever specialistic work and monographs. Indeed Science should be represented to our minds as a building of the ages which can only be raised by the accumulation of enormous masses. A whole life of assiduous labour will only be as an obscure and nameless stone in that gigantic fabric, nay it may be nothing more than an unnoticed stone hidden in the thickness of the walls." But "The perfection of the Parthenon consists above all in the fact that the parts not intended to be seen are as carefully executed as those intended to be seen. So in Science." *

*Renan, *The Future of Science: Ideas of 1848.* 1891. See pp. 32, 115, 208, 209, 215, 217, 221, 476.

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY).

SATURDAY, 17TH MARCH, 1894.

Members having assembled in the Entrance Hall at 3 p.m., Dr. Henry Woodward, F.R.S., P.G.S., Keeper of the Geological Department, personally conducted them through the Gallery devoted to the Fossil Reptilia, and delivered an address in the Fossil Fish Gallery, which was specially reserved for the Association and converted into a temporary Lecture Room. Here Dr. Woodward exhibited a series of diagrams and specimens, illustrating the Amphibia and Reptilia, and pointed out the distinctive characters and chief divisions of the latter class. He then conducted the members round the cases containing the Fossil Reptilia, and indicated all the more important specimens in the Gallery, and their range in Geological time.

The President, Lieut.-Gen. C. A. McMahon, returned thanks on behalf of the Association.

EXCURSION TO BOURNEMOUTH AND BARTON.

EASTER, 1894.

Directo :—JOHN STARKIE GARDNER.

(*Report by* THOS. LEIGHTON, *revised by the* DIRECTOR.)

On *Friday*, 23rd *March*, the coast sections west and east of Bournemouth were examined, beginning with the lowest beds, where they rise from beneath the recent deposits on the east of the entrance to Poole Harbour. A slight dip to the east produces a rising succession as the walk is continued eastwards, but the whole section from Poole Harbour to Highcliff Castle is in the Middle Bagshots. In the London Basin this is a marine series, but Mr. Gardner has shown that at Bournemouth there is an important series of beds (300 feet thick) entirely of fresh-water origin, partly underlying the marine beds, and that the Bournemouth area was, in later Eocene times, the estuary of

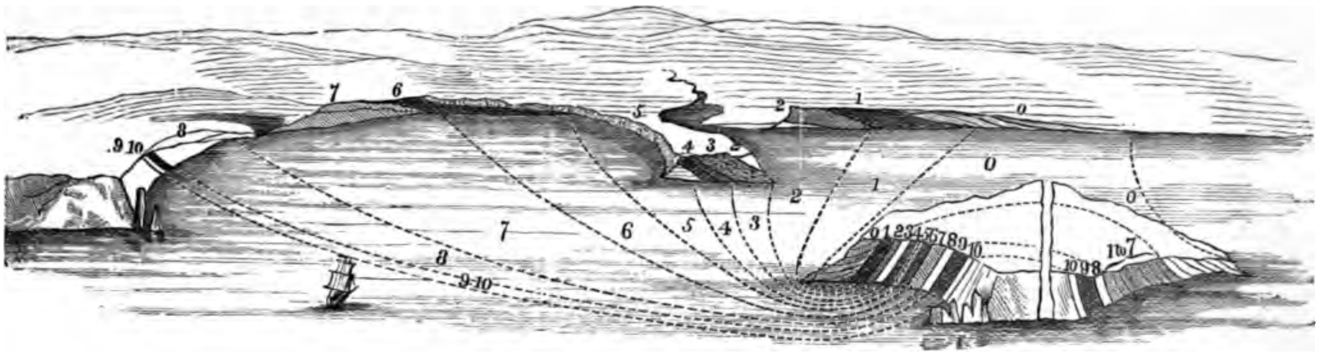


FIG. 1.—IDEAL VIEW OF THE ISLE OF WIGHT AND THE ADJACENT LAND WITH DOTTED LINES CONNECTING THE NEARLY HORIZONTAL BEDS OF THE MAINLAND WITH THE VERTICAL BEDS OF THE ISLAND.—*J. S. Gardner.*

(Reprinted by permission from the *Quarterly Journal of the Geological Society.*)

0. Upper Eocene.
1. Barton Beds.
2. Upper Bracklesham and Highcliff white-sand Beds.
3. Upper Hengistbury-Head Beds, with ironstone.
4. Lower Hengistbury-Head Beds, with green grains.
5. Boscombe Sands.
6. Bournemouth Marine Series.
7. Bournemouth Freshwater Series.
8. Lower Bagshot.
9. London Clay.
10. Woolwich and Reading Beds.

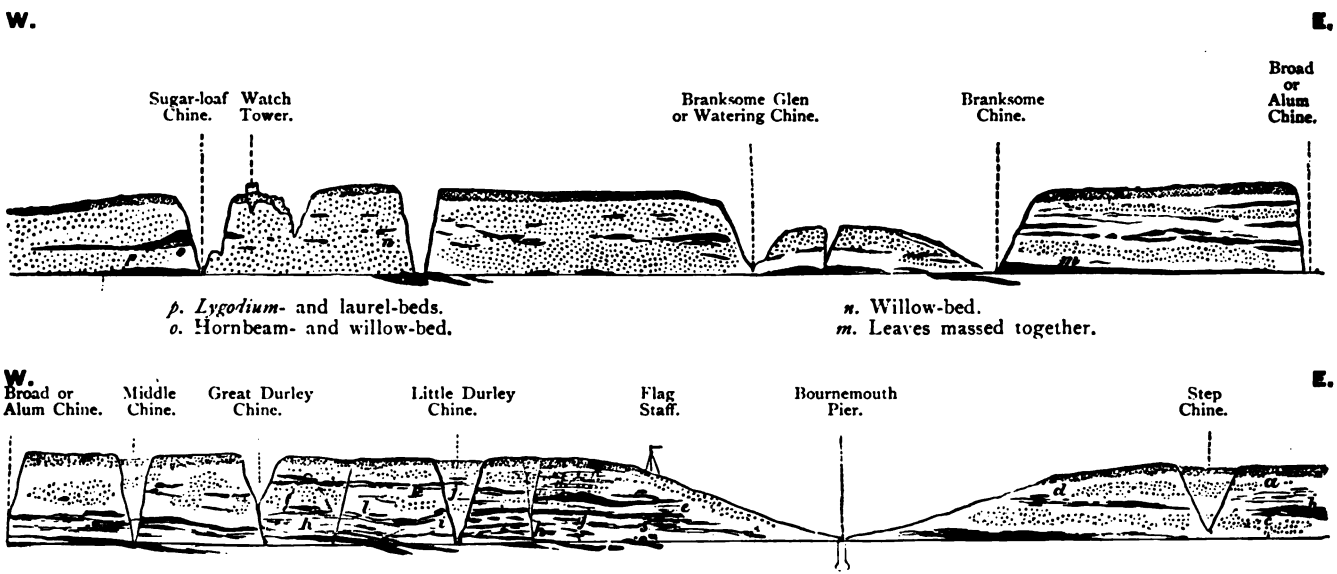
a river, perhaps as large as the Ganges, flowing probably from the south-west through a country of ancient (pre-Jurassic), or igneous, rocks.

The cliffs west and east of Bournemouth display the results of the struggle between this river and the sea. To the west of the pier the cliff shows exclusively fresh-water beds ; in some places clay deposits are seen, in which remains of plants, beetles, flies, feathers, and snails have been covered up in slack waters, occasioned by the constantly varying conditions of the estuary ; whilst, at others, more or less perfect sections of old river channels, devoid of remains of life, are shown. East of the pier the cliffs show a change of conditions, at once horizontal and vertical, from fresh-water to marine ; marine clays are dovetailed into the fresh-water beds, showing how the sea has at times driven back the estuary to succumb to it again after a short interval. This part of the section, just beneath the Bath Hotel, is worthy of careful study ; there are three separate intercalations of marine and fresh-water beds overlapping each other in rising succession, whilst the marine Boscombe Sands with shingle beds cap the whole. To the east of this place the cliffs display only marine beds, the equivalent of the Bracklesham Beds.

It is remarkable that the whole of the deposits to the west of the pier show an entire absence of the wreck of Cretaceous and Jurassic rocks ; either these had been previously eroded from the country through which the Eocene river flowed, or they were below the surface. The detritus is derived from old or from igneous rocks, and consists of clays and pipeclays, and of quartz sand. The sands rarely contain plant remains, but traces of vegetation are seen in nearly all the clays, the best leaves being found in the pipeclays : the horizons of the various leaf beds are shown on the accompanying section, Fig. 2. The leaf beds west of Sugar-loaf Chine appear to contain a different and slightly older flora to those nearer the pier, although no sequence can be made out, by reason of the shifting of the river bed ; still there is a dip of from two to three degrees from west to east. The flora consists of ferns, palms, and leaves of dicotyledons (such as the Hornbeam and Willow), which have inconspicuous flowers—suggesting that dicotyledons with conspicuous flowers are the more recent in evolution. The plants have been drifted from the west into the backwaters in which they lie, owing no doubt to the eddies of the stream. The flora has been but partially worked out ; it contains many South American and East Indian forms and approaches somewhat to the Himalayan, Burmese, and Chinese.

A large number of leaves were found by members of the excursion on this occasion.

On *Saturday*, 24*th March*, the party was enabled to proceed by S.S. *Brodick Castle* to Swanage, through the assistance of Mr. W.



Horizontal scale, 5 inches = 1 mile. Vertical scale exaggerated.

l. Rolled masses of leaves.
k. *Myrica*-bed.
j. Palm-bed.
i. Rolled leaves.
h. Lignitic sand with bored wood.
g. *Gleichenia*-beds.
f. Coast-guard beds.
e. Re-imbedded ferns.
d. Aroid and *Eucalyptus*-bed.
c. Fern-bed.
b Marine clay.
a. Marine sands passing into freshwater.

FIG. 2.—VIEW OF CLIFFS BETWEEN POOLE HARBOUR AND BOSCOMBE, SHOWING POSITION OF PLANT BEDS, ETC.—*J. S. Gardner.*
(Reprinted by permission from the *Quarterly Journal of the Geological Society.*)

Brindley, F.G.S. A course was made close to the Harry Rocks, so that a good view was obtained of the fault in the chalk, which has recently been ascribed by the officers of the Geological Survey to an overthrust. After a peep at the Purbecks in Durlston Bay, the party walked round Swanage Bay, where the cliff section first shows the Wealden. There was some discussion here as to whether these beds had been folded upon themselves, Mr. Gardner suggesting that their great thickness could not otherwise be accounted for. At Punfield Cove the Lower Greensand was carefully examined, and although the section was not in good condition, the *Cypris* Shales at the junction of the Wealden, Mr. Meyer's Lobster Bed, the Marine Band, and other interesting horizons were, after some search, identified. The Gault was recognisable, and the Upper Greensand and its junction with the Chalk were shown by Mr. Whitaker, who also pointed out the various horizons in the Chalk of Ballard Down.

After crossing the Down, the party descended to the shore near Studland, where the junction of the Chalk and the Tertiaries was carefully examined. Mr. Whitaker pointed out that what had been described on the maps of the Geological Survey as "an eroded surface of Chalk" was, as a matter of fact, due simply to solution, of the same nature as that which had formed the well-known 'pipes' of the Chalk area. The party then walked round Studland Bay, and after examining the coloured sands of the Lower Bagshots, similar to, but less known than, those of Alum Bay, proceeded to the ferry across the entrance of Poole Harbour, and so home.

The following day the party drove to Southbourn, and walked thence to Hengistbury Head. The section shows first the shingles of the Boscombe Sands, re-arranged in places as gravels, resting on undisturbed beds of that age; then at the Head itself the bank of the stream which deposited the gravel is shown in section cutting across beds in place. The Ironstone bed of the Head was carefully examined by the party, and was found to contain fossil wood bored by *Teredo*, and sharks' teeth. Above the Ironstone bed is the White Highcliff Sand, the top bed here of the Marine Middle Bagshots (Bracklesham Beds).

On *Monday*, *26th March*, the party proceeded by train to Hinton Admiral, and walked at once to the shore at Highcliff, through the Castle grounds. For the information of members who may visit the district and have not permission to enter the grounds, it may be mentioned that upon reaching the entrance gates the high road should be followed to the east for a short way, when a stile will be found on the right hand, just outside the Castle grounds; the footpath from here leads to a gap in the cliff, from which a descent can be made.

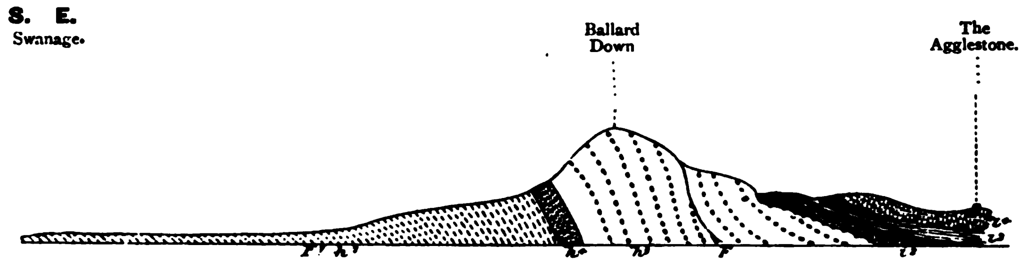


FIG. 3.—SECTION ACROSS BALLARD DOWN FROM SWANAGE TO THE AGGLESTONE.—*After H. W. Bristow.*

This section is drawn a little inland of the actual coast, but so as to express its chief geological features. The fault (F ?) in the Wealden (*h* 1) scarcely reaches the coast. The upper part of *h* 1 contains the "marine-band," the "Punfield Beds," and the uppermost "Lower Greensand." At the base of *h* 4 are dark clays, which represent part of the Gault.

h 1. Wealden or Hastings Series.
h 4. Upper Greensand.
h 5. Chalk.
F. Fault.
i 2. Woolwich and Reading Beds.
i 3. London Clay.
i 4. Lower Bagshot.

FIG. 4.—HENGISTBURY HEAD, WEST SIDE.—*J. S. Gardner.*

(Reprinted by permission from the *Quarterly Journal of the Geological Society.*)

3. White Highcliff Sand.
2. Lower bed with green grains, and upper bed with ironstone.
1. Boscombe Sands.

The party first walked a short way to the west and examined the junction of the Bracklesham with the Barton Beds, marked by the *Nummulina* Zone, which was soon found. Returning, it was found that the interesting section of Lower Bartons, under the Castle, had been entirely destroyed by elaborate, and no doubt necessary, drainage operations for the protection of the Highcliff estate. These Highcliff or Lower Barton Beds contain a distinct and interesting molluscan fauna, in sandy pockets in the clay; the best place to find them used to be a little to the right of the gap in the cliff upon descending from the public foot-path, a little way down the slope. Just at this point the correct horizon was established, by the discovery, on the surface, of a small block containing the characteristic shells, hardened from contact with a septarian nodule; nothing else was found however, or, indeed, is likely to be in the future, unless the clay asserts itself over the patience of its guardians.

The walk was continued eastwards to the fossiliferous horizons of the Middle Bartons, where collecting commenced in earnest, and the party having passed the lower band of septarian slabs, and having been previously joined by Mr. Alfred Russell Wallace, F.R.S., then took lunch on the "best fossil zone." Collectors were kept fully employed during the afternoon, as the various horizons (see Fig. 5) of the Middle Bartons and *Chama* Beds (Upper Bartons) were passed. In the sands of the *Chama* Beds a spine of *Cidaris Websteriana* (Forbes) was found by the writer of this report. Although recorded from Barton the horizon of this urchin was not previously known. Upon reaching Becton Bunny the party walked to Milton Station, and returned by train to Bournemouth.

On *Tuesday, 27th March*, the party returned by train to Milton, walked to Becton Bunny, and continued the section eastwards, at the point at which it was left on the previous day. Collecting commenced in the *Oliva Branderi* Zone of the Upper Bartons, and here a test of an urchin, *Hemiaster Branderianus* (Forbes)? was found by Mr. Bowdler, R.E., previously recorded from Barton, horizon unknown. After passing the Long Mead End Beds the junction of the Upper Bartons and Headon Beds at the first lignite band was pointed out. The various horizons of the freshwater Lower Headons of Hordwell, were then examined, and it having been noticed that the Crocodile Bed had thinned out in the cliff, the party proceeded to the steps at Hordwell and walked to Milton Station. Seventy members and their friends took part in this excursion.

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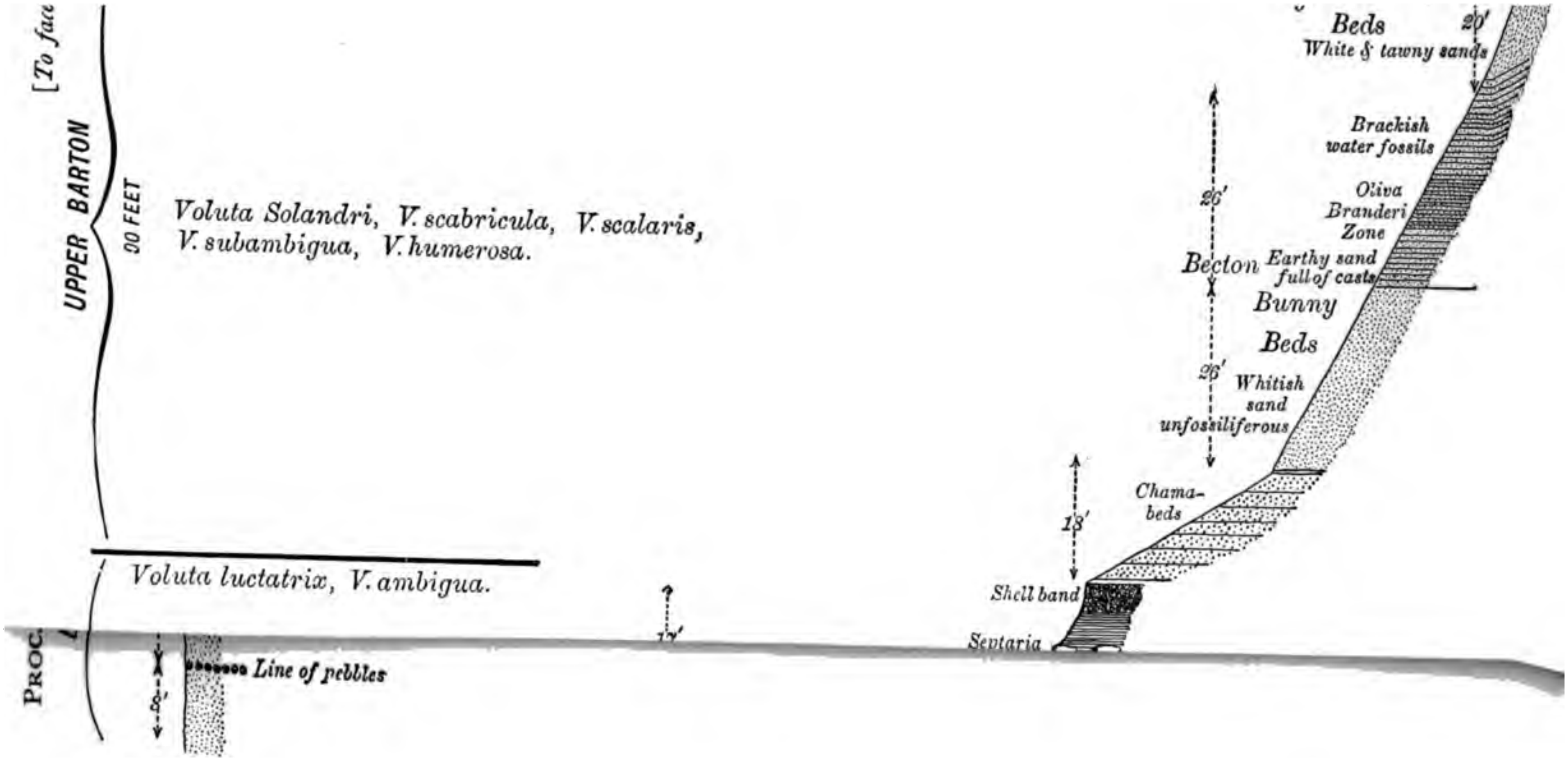

UPPER BARTON
90 FEET
Voluta Solandri, V. scabricula, V. scalaris,
V. subambigua, V. humerosa.
Voluta luctatrix, V. ambigua.
Line of pebbles
8'
17'
Beds
White & tawny sands
20'
Brackish
water fossils
Oliva
Branderi
Zone
26'
Becton
Earthy sand
full of casts
Bunny
Beds
26'
Whitish
sand
unfossiliferous
Chama-
beds
18'
Shell band
Septaria

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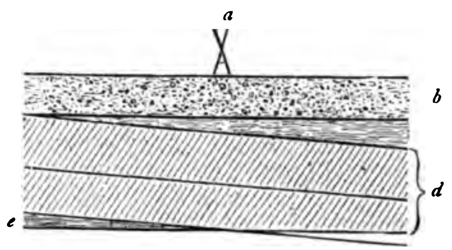

FIG. 6.—SECTION OF BECTON-BUNNY BEDS.

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a. High fence between Col. Clinton's and the Hinton-Admiral estate.
b. Gravel.
c. Long-Mead-End Beds.
d. Becton-Bunny Beds ; *Oliva Branderi* zone.
e. *Chama*-bed.

EXCURSION TO HAREFIELD.

SATURDAY, 14TH APRIL, 1894.

Director: UPFIELD GREEN, F.G.S.

(*Report by* T. V. HOLMES.)

Leaving Baker Street Station at 1.37 p.m., the party arrived at Rickmansworth at 2.16 and proceeded thence in a south-westerly direction, for a distance of about a mile, on the west (or Hertfordshire) bank of the Colne, to a point a little beyond Mill End. Then, turning to the south-east, they crossed the Colne and the Grand Junction Canal and came to the eastern flank of the Colne Valley near Springwell Farm. The sections visited were south of Springwell Farm, and in the hillside east of the alluvium of the Colne and north-west or west of Harefield Park and Harefield Village. The more northerly of the two was a very large chalk pit more than a mile N.N.W. of the village of Harefield, and was especially remarkable, as the Director pointed out, for the number of the pipes in the Chalk and the depths to which some of them had penetrated. The height of the face of the quarry must have been fully 100 feet, and pipes could be seen here and there descending 50 feet or more below the surface. They were extremely irregular in their occurrence, and many of them, having taken a diagonal course, showed themselves in the section as (apparently) masses of gravel, sand or loam surrounded on every side by solid Chalk. It would be difficult to name any chalk pit in which the singular appearances presented by diagonal pipes are better shown: and as the majority of chalk pits seem to be almost or entirely devoid of them, the remarkable appearances they present in this Harefield section are the more worthy of notice. As to the contents of these pipes, Mr. Whitaker notes (*Geol. Lond. and part of Thames Valley*, vol. i, p. 308) that they consist of "a mixture of Glacial Gravel and Reading Beds, with a growth of clay-with-flints over the surface of the Chalk."

Leaving the great Chalk-pit, the party walked southward to the Harefield Brick and Cement Works. There, in addition to Chalk, the section shows Tertiary Strata from the junction with the Chalk to the lowest beds of the London Clay, the Basement bed of which, though somewhat obscured by a recent landslip, was found to correspond with the description by Mr. Whitaker, consisting of about 6 feet of brown sandy clay with few pebbles and a layer of decomposed shells, and containing calcareous inclusions in which the shells are better preserved. Members of the Association familiar with similar sections in north-west Kent, such as those at Loampit Hill, Lewisham, could not fail to note the absence of any bed resembling the Thanet Sand of Kent and the southernmost corner of Essex. It was also obvious that the strata at Harefield corresponding in position to those of the Woolwich series contained much red and mottled clay, or, in other words, were of the Reading, not the Woolwich, type. The Director called especial attention to the strata at and close to the junction of the Tertiary Beds with the Chalk, which were very clearly shown. In the topmost layers of Chalk, down to a depth of a foot or more, were many tubular borings, with a diameter varying on the average from perhaps 2 inches to less than half an inch, and very irregular as regards their direction. They were filled chiefly with green sand, but occasionally a small flint pebble might also be seen. Directly above the Chalk was a band with an average thickness of about 2 feet of green coated flint pebbles, a novelty at this horizon.

Turning eastward the party entered the village of Harefield, where they were at first supposed to be supporters of a certain "Good Old Brown" (a candidate for some local office, the election to which seemed to be going on), and received with warm but fleeting enthusiasm. They thence proceeded northward to Rickmansworth by way of Woodcock Hill Kiln, which has been previously visited by the Association. After tea at the Victoria Hotel, close to the Metropolitan Station, and the passing of a hearty vote of thanks to the Director, they departed for London, congratulating themselves that the rain then falling had not come early enough to interfere with the success of a most interesting excursion.

EXCURSION TO WELLINGBOROUGH.

SATURDAY, 28TH APRIL, 1894.

Directors: BEEBY THOMPSON, F.C.S., F.G.S., AND W. D. CRICK, F.G.S.

(*Report by* BEEBY THOMPSON.)

THE members arrived at Wellingborough soon after ten o'clock in the morning, and at once proceeded to the furnaces of the Wellingboro' Iron Company, Limited, about three quarters of a mile due north of the Midland railway station. Here they were courteously received by the manager, Mr. Herbert Pilkington, F.C.S., M.I.Mech.E., and conducted over the works.

The ironstone and limestone used at these furnaces are obtained from the workings in the direction of Finedon, visited later on by the members.

First of all, the method of drying the stone was shown, and it was pointed out that roasting was not necessary, as by far the greater portion of the ore was already in the form of oxide; the operation was, however, sufficient to convert any carbonate present into oxide.

The lower portion of the ironstone beds of the Northampton Sand, in this neighbourhood, is sometimes green in the interior of the blocks, indicating a carbonate of the protoxide of iron, but is not of that bluish green colour seen in the equivalent beds at Northampton, and which, indicating phosphate of iron (Vivianite), causes the rejection of the ore for furnace purposes. Mr. Pilkington said it was not necessary to reject any of the ore they were working on this account.

Most of the visitors ascended to the top of the towers by the lift, and there saw the method of simultaneously precipitating into the furnaces the proper quantities of lime, coke, and ironstone. All the various arrangements for utilising the otherwise waste combustible gases, and for producing the blast, etc., were also shown and explained.

The pig iron is run on to sand obtained from Courteenhall, near Northampton, a drift deposit apparently almost entirely consisting of redeposited Northampton Sand. This sand is selected in preference to any other because of its extreme porosity—it does not cause spurting of the iron through the generation of steam, even after continued rain—and because it does not cling to the iron and so introduce silica. The section from which this sand comes was visited by the Geologists' Association during the Whitsuntide excursion of 1891.*

SECTION OF UPPER LIAS CLAY.

Close to the furnaces, and worked by the same Company, is a brickyard, described under the name of Rixon's pit in the Journal of the Northamptonshire Natural History Society in 1888.† It then presented a good section of the Lower *Leda-ovum* or *Cerithium* beds. At the present time the working is some 20 feet deeper, and in the most unfossiliferous part of the Lias, so very few fossils were obtained. A few large Ammonites, mostly or entirely converted into iron pyrites, were lying about because carefully rejected in working the clay, and amongst these *Ammonites exaratum* and *A. Holandrei* alone were identified with certainty, though probably *A. bifrons* was also one. This is just the character of the Upper Lias beneath the *Cerithium* beds at Northampton.

Attention was called to the capping of Northampton Sand, the clay on which it rested being at the lower portion of the *Leda-ovum* beds, and so probably more than 60 feet below the highest Upper Lias beds of the district. This peculiarity was explained as a common characteristic of hill-side sections, the result of slipping during the formation of the contiguous valleys.

A short visit was next made to the Chemical Laboratory connected with the furnaces, where analyses of the ironstone of the neighbourhood were inspected. Appended is an analysis of one of the ores then being worked from a pit (not visited) known as the Ditchford pit, a little over a mile S.E. of the Finedon Hill section:—

Moisture	4·07
Metallic Iron	36·80
After drying at 212° F.	
Silica	25·20
Alumina	9·98
Oxide of Manganese	0·39
Lime and Magnesia	traces
Phosphoric Acid	1·615
Ferric Oxide	52·60
Loss on Ignition	10·40
	100·183

* *Proc. Geol. Assoc.*, vol. xii, p. 179 (Nov., 1891).
† Vol. v, p. 54, 1888.

Two engines were then kindly placed at the disposal of the party, by which they were rapidly conveyed on the Company's private line to a point near to Finedon village. Here a halt was made for luncheon, after which the members proceeded to examine the various sections then in work for limestone and ironstone. It would have been better to have examined the sections in the reverse order to that actually taken, as the most complete and typical section, that near Finedon Hill Farm, would have been visited first; but some of the members had had a very early breakfast.

It is probably rare to find within such a small superficial area—only about half a square mile, *i.e.*, one mile N. and S. by half a mile E. and W.—such a large exposure of rock. There are at least ten long faces, of which five were then in work.

The district is peculiar in several respects; it is gently undulating, and traversed in several places by "faults." The undulations are, however, not so much due to surface denudation as usual, but rather to curves in the strata themselves. This characteristic is probably due to the fact that all the beds, where not covered by Boulder Clay, are very porous; indeed several small streams rising in the higher ground do not reach the valley as such, but lose themselves in the Northampton Sand outcrop on the side of the hill.

No. 1.—The first section visited (Mr. Neilson's) lies immediately to the east of Finedon village. Here the ironstone comes quite to the surface, though not shown so on the maps, probably because occupying too small an area. The stone is a rich ironstone of the usual character, *i.e.*, jointed, and with innumerable cases or boxes of iron oxide containing more sandy nuclei, and varies in thickness from 10 to 14 feet. It is carried down to the railway, about a mile and three-quarters, by trucks running on an endless cable. The top of the ironstone is about 274 feet O.D., while the bottom of the ironstone at the furnaces is about 172 feet O.D., so that, allowing 12 feet for the thickness of the bed, there must be a difference of 90 feet in height of the Upper Lias surface.* Towards Finedon the ironstone dips, bringing in some of the limestone beds. Also the beds dip (more rapidly than the ground) towards a small stream to the S.E., for higher beds, are met with in that direction. (See next section.)

No. 2.—The next opening visited was one worked by the Wellingboro' Iron Company, and the section runs nearly E. and W., the easterly end coming right up to the southerly end of the last described, and as this is at right angles to the direction of dip, or parallel to the fold, the beds are nearly horizontal.

* The heights are only approximately correct: they were taken with a Watkin compensated Barometer on a day when the Barometer was rising (=55 feet in 7 hours).

SECTION NEAR FINEDON.

		ft.	in.
Great Oolite Limestone.	1. Soil and limestone, the latter in small flat pieces, largely crystalline, and highly fossiliferous. Ferruginous base, sharply separated from No. 2.	4	10
Upper Estuarine Beds.	2. Greenish grey clay, blue in places, with vertical plant markings	1	10
	3. Red sandy layer	0	3
	4. Variable bed—sand, clay, marl, and limestone, some of the latter hard blue hearted stone.	6	6
	Where best to be examined as below :—		
	(*a*) Grey clay—no fossils, 1 foot.		
	(*b*) Sandy marl—few fossils, 1 foot.		
	(*c*) Hard white layer — less sandy, more a limestone, fossils abundant, 2 feet.—*Cyprina Loweana*, *C. Islipensis*, *Cyrena* sp ?, *Cucullæa* sp ?, *Placunopsis* sp ? *Modiola imbricata*, *Ostrea* sp ?		
	(*d*) Brown argillaceous limestone, white towards base — many fossils, 1 foot ; *Ostrea Sowerbyi* ; *Modiola imbricata*, *Cyprina*, *Placunopsis socialis*.		
	(*e*) Extremely variable layer, brown and white, quite an oyster bed at base, 1 foot 6 inches ; *Ostrea Sowerbyi* chiefly ; *Modiola imbricata*.		
	5. Blue clay crowded with oysters ; *Ostrea Sowerbyi*	1	6
	Unconformity—position of Lincolnshire Oolite.		
	6. Irregular ruddy band, thickening to a bed here and there as a stratified sand, by encroachment on bed next below		
Lower Estuarine Beds.	7. Bluish grey sand, or sandy clay ; vertical plant markings abundant in places. This bed varies greatly in thickness, and in some places is quite absent, from encroachment of the ironstone. In places good rich ironstone goes right up to the base of bed 5	4	0
Ironstone Beds.	8. Ironstone of the usual form ; some green layers of carbonate towards the base. Very undulating upper surface for the reason assigned above. No fossils noticed	10 to 14	0

The ironstone at this section, and others close to Finedon (the last one) is very rich. An analysis shown to me by Mr. Pilkington gave 43·69 per cent. metallic iron and 17·7 per cent. silica, after drying at 212° F.

The top of the ironstone is here about 257 feet O.D., which represents a drop of about 17 feet from the last section.

Three other similar sections near the above were not visited.

IRONSTONE WORKING, FINEDON HILL.

From a Negative by Mr. G. Nichols.

No. 3.—About half a mile further south a long working face of Great Oolite limestone, running E.N.E., was visited. The section at the eastern end, where it is deepest, chiefly through the rising of the surface in that direction, is as follows:—

	ft.	in.
1. Soil and Chalky Boulder Clay	9	6
2. Limestone in many courses, mostly very hard .	23	0
3. Estuarine Clays (dug into for making a drain) .		

The top of the Great Oolite here is about 285 feet O.D., and therefore the top of the ironstone is probably about 244 feet O.D., that is about 13 feet lower than at section No. 2.

No. 4.—The fourth section visited is very much like No. 2 nearer Finedon, except that the beds just above the ironstone are still more variable in colour and consistency, blue and red, and clay and stone being very much mixed. There is really very little of the Lower Estuarine bed to be seen, the ironstone going right up to the blue clay of the Upper Estuarine beds (the Oyster bed).

This section runs approximately N. and S., and all the beds here form a gentle syncline, with a curvature rather greater than the surface of the ground. There is a slight rise evident at the northern end, and a more considerable one to the south, where it joins on to the main ironstone working. The top of the ironstone is about 245 feet O.D., 29 feet lower than at Finedon, and 12 feet lower than at section No. 2.

They have recently been connecting this working with another to the south nearly at right angles to it, and in order to do so it was necessary, both on account of the rising of the beds to the south, and of a small fault running approximately E. and W., producing an uplift to the south of about 10 feet, to cut through a good thickness of Upper Lias Clay.

The Upper Lias is here moderately fossiliferous, but the fossils are poor; nevertheless they were sufficient to show, as might have been expected, the highest beds. The fossils found then and since include:—

Leda ovum (many).
Pecten demissus.
Monotis substriatus.
Protocardium substriatulum ? (poor specimen).
Ammonites bifrons.
Hinnites velatus (in the clay just below the junction).

The base of the Inferior Oolite is marked by a line of small nodules; otherwise, at a little distance away, the true junction could scarcely be determined. The ironstone is not obviously fossiliferous, though one good specimen of *Terebratula perovalis* (?) was found in the unoxidized portion close on to the clay. The top of the clay here is about 245 feet O.D., or 73 feet above the top at the furnaces.

No. 5.—The chief face of ironstone hereabouts runs in a curve, having a general E. and W. direction; the ore comes quite to the surface, in the form of a dome, though the southern slope is cut by two faults, one the long E. and W. fault shown on the geological maps, and the other running in a direction N.W. by S.E. One of these faults crosses the eastern end of the workings at a very acute angle; it appears to be the N.W. and S.E. one not shown in the maps, but at this point the throw is not considerable; the bottom of the Lower Estuarine sand is brought into touch with the upper part of the Lias Clay. Probably this is just about where the two faults meet, or cross each other, as for a good distance the beds are much contorted. The top of the ironstone at the highest part of the working here is 30 feet above the top of the ironstone in the other working quite near, and this difference of level is only partly accounted for by the small 10 feet fault between them.

At the westerly end of the section the ironstone suddenly ceases, the Cornbrash abutting against it. The "fault" which causes this runs in a direction about S.E. by E, and so cannot be the one marked on the maps, which latter runs about E. by N. The drop is probably about 55 feet, made up as shown below:

	ft.	in.
Cornbrash	3	0
Great Oolite Clay	8	0
Great Oolite Limestone	22	0
Upper Estuarine Beds	14	8
Lower Estuarine Beds	7	4
	55	0

No. 6.—In the next field, to the west, and only a few yards away, at the place marked "Lime kiln" on the geological maps, the following section was seen:

		ft.	in.
1.	Cornbrash; rubbly limestone, mixed with soil, containing *Avicula echinata*, *Pecten vagans*, etc.	1	0
2.	Great Oolite Clay; dark purple clay	8 0 to 9	0
3.	Great Oolite Limestone; two beds of stone, the lower one showing many fossils on the weathered surface; *Trigonia*, *Acrosalenia*, *Gasteropods*, etc.	3	0

The limestone is said to have been continued down another 13 feet, and if so, it means that the limestone series here, down to the base of bed 2 in the next section, is 16 feet thick. This seems rather too little (*see* p. 287).

Just a little further westward, on the other side of the Ditchford road, is the most complete section to be seen in the neighbourhood. It has not been worked for some time, because the ironstone got too deep.

No. 7.—Section near Finedon Hill Farm.

Great Oolite.

Series	Bed	ft.	in.
	1. Soil and disturbed limestone; soil about 1 ft. . . .	3	10
Limestone Series.	2. Limestone in blocks. Two courses of white stone separated by 4 inches of marl just about the middle; same fossils throughout. *Ostrea*, *Rynchonella concinna*, and *Modiola imbricata* very abundant; *Isocardia*, *Pholadomya*, and *Spines of Echinoderms*, fairly common. *Modiola*, most abundant just at the top of the lower course of stone.	3	8
	3. Ferruginous clay, dirty looking, very few fossils . .	1	0
	4. Marl and clay; may be divided into several distinct beds, although the fossil contents are about the same throughout . . . . (*a*) Light coloured marl, very fossiliferous; *Rhynchonella concinna* abundant . . . . 6 in. (*b*) Blue clay, fewer fossils; *Rhynchonella* the most abundant form . . . . 8 in. (*c*) Layer like (*a*) . . . . 8 in. (*d*) Layer like (*b*) . . . . . . 10 in. Fossils in (*c*) and (*d*) mostly fragmentary—*Ostrea*, *Rhynchonella*, etc.	2	8
Upper Estuarine Series.	5. Dark blue clay, with numerous vertical *plant markings* and bits of *carbonaceous matter*. The vertical stems are iron-stained and very fragile, some of them ¼ in. in diameter . . . . Light green calcareous clay, with vertical plant markings . . . . [These two beds are taken together because whilst each is variable they maintain about the same joint thickness].	2	10
	6. Indurated green clay, weathering red on the surface; almost a limestone in the upper part, and a calcareous sand or sandstone in the lower . . . . . *Plant markings* fairly abundant in the upper part and absent in the lower . . . . *Ostrea*, *Cyrena*, *Spines of Echinoderms*, etc., in lower part	2	2
	7. Hard fossiliferous limestone, nearly white, only differing from some parts of (6) in colour and hardness . *Isocardia*, *Placunopsis socialis* (many), *Cyrena*. .	1	0
	8. Reddish sand, becoming stony in places, few fossils .	0	10
	9. Limestone; several beds not sharply defined: (*a*) Limestone similar to No. 7. . . . . . (*b*) Very fossiliferous white layer . . . . . (*c*) Sandy marl, dirty coloured, with *Ostrea*, *Echinoderm spines*, *Cyrena* . . . . . . 1 ft. 6 in. (*d*) Layer like (*b*); *Ostrea*, *Spines*, etc. . . .	3	8
	10. Soft sandstone, no fossils	1	0
	11. White marl, very fossiliferous; *Ostrea Sowerbyi*, *Cyrena*, *Cardium Stricklandi*, *Corbula attenuata ?* .	0	10
	12. Ferruginous clay or shale. The base is still more ferruginous, and quite an *Oyster bed*. *Rhynchonella* (good specimens) also abundant	1	10
	13. Reddish sandstone, upper part resembling No. 12 in fossil contents. No fossils just at base. A kind of Transition bed	0	6

INFERIOR OOLITE.

		ft.	in.
Position of Lincolnshire Oolite.	14. Yellowish or red sand, well stratified; frequent alternations of redder and whiter sand give it a pretty banded appearance when freshly cut; no fossils. Sharp clean junction with bed below, and no sign of erosion	2	4
Lower Estuarine Beds.	15. Whitish argillaceous sand, inclining to purple, ferruginous in places. More clayey at top and bottom than in the middle, and just at bottom quite blue. *Vertical plant markings* most abundant, best seen at the top. Much *Carbonaceous matter* in the blue part at base. Junction with No. 16 clean and well defined	5	0
Ironstone Beds.	16. Ironstone in large blocks, not apparently cellular where got from a good depth, though on the ridge of the hill, where it comes very near to the surface, it is. Some green blocks near the bottom . .	13	0
	Below this, according to men, soft red stone, with much water and then clay		
	Total depth	46	0

As there are many points of interest in connection with this section, a photograph of it is reproduced in Plate VII. The section there shown runs almost east and west, and is seen from the south; it is almost exactly parallel to the great east and west fault shown on the maps of the Geological Survey, and only just a little north of it, cutting the private road to Finedon Hill Farm, and just west of the limekiln marked on the maps.* I think, however, the fault should be a trifle further south.

The beds rise at an angle of about nine degrees towards this east and west fault, and consequently sink to the north; this fact, whilst providing us with such an interesting section, has rendered the getting of the ironstone unremunerative.

The beds besides dipping to the north dip rapidly to the east (right of the photograph), at an angle of eight or nine degrees, and ultimately are cut off by the other fault running S.E. and N.W., which brings the top of the ironstone beds into contact with the Cornbrash. (See No. 5, p. 288).

In the Plate the chief beds are numbered to correspond with the description. Thus, beds 1 to 5 reach to the highest working shelf, though this shelf cuts through bed 5, some parts being above it to the west, and some below it to the east. The next working shelf coincides with the junction between beds 14 and 15.

No. 8.—Following the last section westward led the party into another ironstone working, having a direction about N.N.W. from the last. At the northern end of this the ironstone nearly dies out, apparently through encroachment of the white sands of the Lower Estuarine beds from above downwards. It will be noticed that this is the reverse of what was seen in sections No. 2 and No. 4, and shows the intimate connection of the two sets of beds.

* This limekiln is not there now, though the section is still to be seen (No. 6).

After leaving the last section the members proceeded to Wellingborough. It was originally intended to visit one or more Upper Lias sections to the west of that town, but, as there was only about time left to walk to them and back again, this part of the programme was abandoned by general consent on reaching the door of the hostelry.

A meat tea was provided at the Hind Hotel, and the members left Wellingborough by the 6.19 train for St. Pancras.

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EXCURSION TO OXTED AND TITSEY.

SATURDAY, 5TH MAY, 1894.

Directors: G. LEVESON-GOWER, F.S.A.; AND W. TOPLEY, F.R.S.

Upon arrival at Oxted Station the party proceeded to the adjoining sand-pit, where was seen a fine section of the Folkestone Beds, showing the usual false-bedded coarse iron-stained sand with much ironstone. A remarkable feature of this pit is the ironstone, which exhibits concretions of all kinds, and clusters of pipe-like formations close together, resembling the barrels of a military machine-gun. Further than the general statement that they are due to some form of infiltration, no explanation was offered as to their origin. It is worthy of notice that in spite of the false-bedding, the general northerly dip of the beds can be traced in this pit.

The party then proceeded to a second sand-pit, near the Church, where higher beds of the Folkestone Sands are seen, white sands without ironstone but with traces of diffused iron, the usual condition of things in this part of Surrey. The party then divided, one section to visit a pre-historic barrow and old manor-house, the other the Greystone Lime Works in the Lower Chalk.

Upon the reunion of the party, the ascent of the Chalk escarpment was made, and the walk continued along it to Coldharbour Beeches, from which there is an extensive view over the vale of Holmesdale, the dip slope of the Lower Greensand showing well in the foreground, to the Weald, with the Forest Ridge and South Downs on the southern horizon. After descending to Titsey Place, where the party was hospitably entertained by Mr. Leveson-Gower, the remains of a Roman Villa were visited in the park, and the return commenced to Oxted Station.

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EXCURSION TO CAMBRIDGE AND ELY.

WHITSUNTIDE, 1894.

Directors: PROF. T. MCKENNY HUGHES, F.R.S., AND JOHN E. MARR, F.R.S.

(*Report by* J. E. MARR AND THOS. LEIGHTON.)

On *Saturday*, 12*th May*, the party assembled on the Castle Hill, where Prof. Hughes gave a description of the geology of the district and pointed out the position of the pits to be visited. A short walk along the river Cam brought the party to the gravel pit at the junction of the Milton and Chesterton Roads. Although the Pleistocene Gravels have been worked out at Barnwell, this pit is in the same gravel sheet, and fossils may be always obtained when the shell-marls are struck. An opening was made by two workmen upon the arrival of the party, and in a few minutes quantities of fossils were thrown out—*Corbicula fluminalis*, *Succinea putris*, *Helix nemoralis*, *H. arbustorum*, *H. hispida*, *Planorbis marginatus*, *Limnea peregra*, *Bythinia tentaculata*, *Valvata piscinalis*, *Pisidium amnicum*, *Unio*, and small *Pisidia* were at once recognised. Teeth of *Elephas* and mammalian bones were also seen in the possession of the workmen. The party afterwards proceeded to Barnwell, where two pits showing the Chalk Marl, Cambridge Greensand and Gault were examined. The Cambridge Greensand should not be confused with the Upper Greensand, although, like the latter, it lies between the Gault and the Chalk Marl. The Cambridge Greensand is a thin remanié bed at the base of the Chalk Marl (to which it properly belongs) containing derived fossils supposed to come from the upper part of the Gault, and contemporaneous fossils similar to those in the overlying Chalk Marl. On account of its wealth of phosphates it has been extensively worked commercially and is now almost exhausted at Barnwell. It has yielded a remarkable fauna, which is well illustrated in the Woodwardian Museum and elsewhere. The surface of the pits, and the waste heaps, are strewn with the phosphatic nodules, and many characteristic fossils were collected by the party. In the second pit visited, close to the station (Barnwell Junction), the Cambridge Greensand can still be seen *in situ*.

On the following day the party was received by the directors at the Woodwardian Museum, the more noteworthy contents of which formed the subject of a demonstration by Prof. Hughes.

On *Monday*, *14th May*, Mr. James Parker's store of archæological lore was once again freely drawn upon in a hurried visit to the colleges, and at midday a party, fifty-two in number, assembled at the station for a visit to Upware. From Burwell Station the party walked to the Burwell Lode, and proceeded by barge on the "Fen drain" (Dutch dyke) to Upware. The so-called "Fen drain" is everywhere above the level of the surrounding country, and commands a fine prospect of the fen and fen-land through which it passes. A halt was made three-quarters of a mile from the starting place, at the Burwell Super-phosphate Works, which were visited by permission of Mr. W. Colchester. F.G.S. The phosphate now worked is chiefly imported from America, and as the material is extremely fossiliferous a unique opportunity was afforded, and freely taken advantage of by the party, for the collection of Charlestown fossils. After lunch at the Upware Inn, as much time as remained was devoted to an examination of the neighbouring quarry in the Coral Rag. The party then returned to Cambridge by the same route.

Tuesday, *15th May*.—The members of the Association travelled to Ely, and proceeded on foot to the Roswell (or Roslyn) Hill Pit, north of the city, on the left bank of the Ouse. They found themselves standing on the edge of the elevated ground forming the Isle of Ely, which owes its superior height partly to a capping of Lower Greensand, and partly to the existence of bands of septarian nodules in the Kimeridge Clay. After studying the general characters of the fenland, and contrasting them with those of the Chalk escarpment to the east, the attention of members was directed to the remarkable assemblage of Boulder Clay, Chalk, Cambridge Greensand, Gault, and Lower Greensand, which (once supposed to occur here owing to faulting) is now generally recognised as a large boulder resting on Boulder Clay. Although the Cretaceous beds of the boulder were not well exposed, members were able to judge of its large (though by no means very exceptional) size. A good section of the Boulder Clay enabled members to recognize the characteristic Chalky Boulder Clay of East Anglia with striated chalk pebbles, flints, Kimeridge shale, Lias gryphites, etc.

Proceeding towards the western end of the pit, discussion arose concerning the nature of a stratified gravel, which seemed to rest unevenly on Boulder Clay, the prevalent opinion, as expressed by members, being that it was a portion of the Glacial series.

On reaching the opposite side of the pit, the thin deposit at the top of the Kimeridge Clay, as seen in this pit, was briefly examined, but no specimens of *Discina latissima* were obtained by the party. They were more successful, however, amongst the shales forming the upper part of the Lower Kimeridge Clay occurring below the upper band of septarian nodules, and many good specimens of *Exogyra virgula*, *Astarte supracorallina*, *Lingula ovalis*, *Trigonellites latus*, etc., were obtained here. The members were fortunate in seeing an excavation in the clay below the water-level, which was not exposed when Mr. Roberts worked out the detailed succession of the Roswell Pit beds, and amongst other finds obtained here were some remarkably large individuals of *Rhynchonella inconstans*.

Alter a lunch at the Lamb Hotel, some of the party visited the interesting local collection made by Mr. Marshall Fisher, which he kindly threw open to members of the Association. All the members of the party afterwards visited the Cathedral, and enjoyed the pleasure of listening to an exceedingly interesting account of its history and architecture, given by Mr. James Parker, of Oxford.

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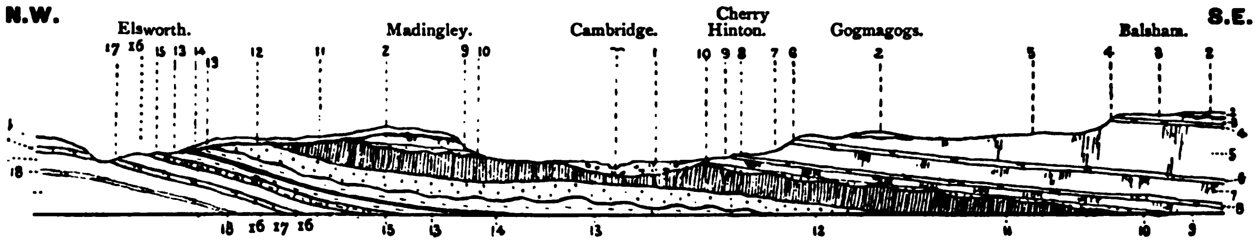

DIAGRAM SECTION FROM ELSWORTH, BY CAMBRIDGE, TO BALSHAM.

(*Vertical scale about* 800 *feet to an inch. Length of Section*, 21 *miles.*)

⌄ The Cam and its Alluvium.	9. Chalk Marl.
1. Gravel.	10. Cambridge Greensand.
2. Boulder Clay and Deposits derived directly from its waste.	11. Gault.
3. Upper Chalk.	12. Lower Greensand.
4. Chalk Rock.	13. Kimeridge Clay, with
5. White Chalk.	14. Subordinate Limestones of Knapwell, Littleport, etc.
6. Melbourn Rock.	15. Corallian, with Upware Rock and other Sandy Limestones.
7. Cherry Hinton Chalk.	16. Elsworth Rock.
8. Totternhoe Stone.	17. Oxford Clay, with
	18. Subordinate Limestones.

VISIT TO THE MUSEUM OF MR. F. C. J. SPURRELL, F.G.S., AT BELVEDERE, KENT.

SATURDAY, 10TH MARCH, 1894.

(*Report by* MR. SPURRELL.)

THE party arrived at Belvedere about 3 p.m. and proceeded to Mr. Spurrell's house, where a local collection of flint implements, cores, etc., was inspected. It included the restored flint figured in *Quart. Journ. Geol. Soc.*, vol. xxxvi (1880), pl. xxii. Mr. Spurrell gave an account of some methods used by prehistoric man in flaking flint.

After the members had inspected the collection and partaken of tea, they proceeded across Bostall Heath and Woods to the East Wickham brickfields. The brick earth here is banked up against the Woolwich Beds and Thanet Sand, and rests at its lowest on the Chalk. A few fossils were produced which had been recently found here.

The party then returned from Plumstead station to London.

THE GEOLOGY OF SOUTH SHROPSHIRE,

WITH SPECIAL REFERENCE TO THE DISTRICT TO BE VISITED DURING THE LONG EXCURSION.

By Prof. C. LAPWORTH, LL.D., F.R.S., and W. W. WATTS, M.A., F.G.S.

[*Read 6th July, 1894.*]

CONTENTS.

I.—INTRODUCTION.

FROM whatever point of view we regard the district to be visited by the Geologists' Association in 1894, whether from its association with so many of the Fathers of British Geology, from the variety and nature of its rocks, the frequency and perfect preservation of its fossils, the complexity and systems of its tectonic structure, or from the beauty of its scenery, it is one of surpassing interest. In classic times it formed the eastern portion of the land of the Ordovices, while it was bounded immediately to the south by the realm of the Silures. Within the last half century its hills, its towns, and its very hamlets have become familiar to the geological student throughout the world. The Longmynd, Rushton, Uriconium, Comley, Shineton, the Stiper Stones, Caradoc, Wenlock, Ludlow, Aymestry, and Downton all give names to important rock groups which have passed into common geological knowledge, while there yet remain many minor divisions which the progress of the science may prove to be type stages and zones, a system of units to which deposits of other areas will eventually be referred.

There are comprised within the county representatives of almost every known horizon from the Longmyndian to the Lias, brought into close approximation by a cluster of unconformities which Mr. D. C. Davies first drew attention to in a paper to this Association* and upon which Professor Blake has justly remarked,

* *Proc. Geol. Assoc.*, vol. ii, 1873, p. 299.

There are folds, faults, and igneous rocks of all ages; scenery of all types, from the rolling mountain range of the Longmynd to the noble Wenlock Edge escarpments and the broad Midland Plain. The county is now fairly accessible to the geologist, and it only needs to be added that its structure has been studied and described by such men as Lewis and Murchison, Aikin, Prestwich and Lightbody, La Touche and Symonds, Allport and Bonney, Maw, Morton, Callaway, Blake, and Cobbold.

It will be best, after giving a general notice of the principal physical features of the county, first to describe the sequence of rocks in Shropshire so far as it is at present understood, and subsequently to give a brief historical summary in order bring out more clearly the successive stages by which the structure has been worked out. In this way attention can be drawn to the different series in order, in such a manner as to bring out those salient characteristics which have rendered the individualization of each system a possibility. We do not propose, however, to enter into every detail of the history of geological discovery and controversy; nor have we space to do justice to all the individual workers who have completed the fabric of our present knowledge.

II. PHYSICAL STRUCTURE.

One of the greatest fracture-lines known in British Geology is that which sweeps, from N.E. to S.W. in direction, from Lilleshall Hill through the Wrekin and Stretton Hills down to Kington in Radnorshire. A fault of great throw, often splintering up into a host of minor fractures, runs along this line and brings up ancient rocks into unwonted contact with such newer divisions as the New Red Sandstone, Carboniferous, and Silurian rocks. The physical features of Southern Shropshire may be regarded as built up on and around this line. Centrally we have the Longmynd, a great moorland relic of a plain of marine denudation, carved out by streams into deep valleys or "gutters" which have isolated the lumpy, apparently structureless, hills that diversify its surface. Here however, as elsewhere in the county, traces of a later marine denudation are to be seen in the old sea cliffs, low lines of hills sometimes two or three miles long, against which the Silurian floor

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FIG. I.—SECTIONS:—II, Fig. 6; III, Fig. 13; IV, Fig. 9; V, Fig. 10; VI, Fig. 7; VII, Fig. 8.

LOCALITIES:—(1) Wellington; (2) The Wrekin; (3) Rushton; (4) Charlton Hill; (5) Lea Rock; (6) Walcott; (7) Leebotwood; (8) The Lawley; (9) Caer Caradoc; (10) Church Stretton; (11) Pontesbury; (12) Nill's Hill; (13) Minsterley; (14) Mytton Dingle; (15) Roman Gravels; (16) Hope; (17) Chirbury; (18) Priest Weston; (19) Llanfawr; (20) Corndon; (21) Whetstone; (22) Fishpool; (23) Craven Arms; (24) Horderley; (28) Cressage; (29) Belswardine Brook; (30) Buildwas Abbey; (31) Lincoln Hill; (32) Coalbrookdale.

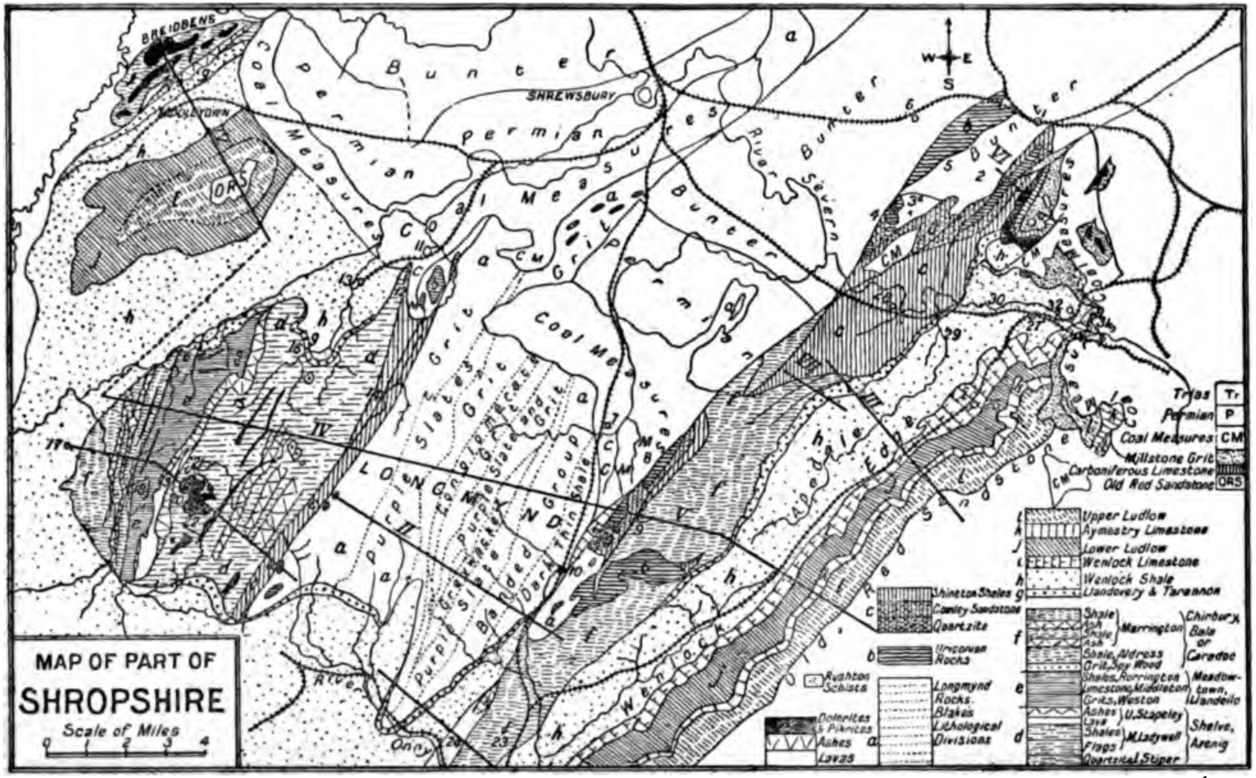

FIG. 1.—The Map is based on the Index Map of Wales, Sheet 15, of the Geological Survey, with modifications taken from the papers of Dr. C. Callaway and Professor J. F. Blake, and from unpublished observations by Professor C. Lapworth and Mr. W. W. Watts. The scale does not admit of the introduction of more minute subdivisions, although these have been mapped, nor does it allow of more than a diagrammatic representation in many parts.

lies as the sea under Beachy Head to-day. Round the Longmynd comes a ring of volcanic hills extending from the Wrekin to Church Stretton, and back from Chittol to Pontesbury, each hill an isolated hog-back with abrupt sides and more gently sloping N.E. and S.W. ends, giving rise to features which are always striking from the changing and unexpected nature of their outline. Beyond these, to the West, we have wave after wave of escarpments, all ranging N.E. and S.W. or N.N.E. and S.S.W., rising ridge beyond ridge right away into Wales, wherever a resisting plate of harder rock comes to the surface. The Stiper Stones, Cefn Gwynnlle, the Stapeley Hills, the ridges of Priest Weston, Hagley, and Whittery, the Long Mountain, and the Breiddens are some of these chains which will come under our direct observation. To the east of the Longmynd the structure is the same, and beginning with the escarpment of Hoar Edge we cross those of Chatwall, Church Preen, Wenlock Edge, and Weo Edge, until we reach the Old Red Sandstone county and the swelling heights of the Clees. The escarpments are broken by cross valleys, of which the most important are the Severn Gorge under Benthall Edge, at Ironbridge, and another hardly less interesting, that of the Onny to the south, and these are divided from each other by a typical series of longitudinal valleys, carved out into Apedale, Hopedale, Corvedale, and other dales by the denuding forces to which the relief of the scarps is due. To the north-east the ridges die down under the Shropshire coalfield; to the north-west they are covered up by the great Triassic plain, bearing on its surface the Liassic outlier of North Shropshire.

The regularity of these features is to some extent broken by the intrusion of igneous rocks in a way which at first seems irregular, and also by faults, but it is not difficult to ascertain that even these irregularities conform to the general structure of the district, and are but another expression of the same earth movements to which the main features of the county are due. The geographical order of description above follows to some extent the geological grouping and date of the rocks, the Longmyndian and Uriconian volcanic hills being beyond doubt the oldest rocks, while newer and newer groups are met with as we pass westward in succession over Tremadoc, Arenig, Llandeilo, Bala, Llandovery, Wenlock, and Ludlow strata up to the Old Red Sandstone of the Long Mountain, where a syncline intervenes, and we begin to descend the series again to the Bala rocks of the Breiddens. On the east we cross the *Olenellus* and *Olenus* zones of the Cambrian, the Bala or Caradoc rocks of the Ordovician, and then the divisions of the Silurian and Old Red Sandstone up to the Carboniferous of the Clee Hills and the coalfield of the Forest of Wyre. These relations will be easily understood by reference to the map (fig. 1) and the long section (figs. 9 and 10).

III. FUNDAMENTAL OR PRECAMBRIAN ROCKS.

The base of the Cambrian system of Shropshire cannot yet be said to be mapped out satisfactorily. There occur beneath the fossil-bearing Cambrian Strata three, four, or possibly five groups of rocks whose relative age has not been determined to the satisfaction of all parties, namely the Rushton schists, the gneiss of Primrose Hill, the Uriconian Volcanic series, the Longmyndian Grey Shale series, and the Longmyndian Red Sandstone series. Opinion is much divided on this point, so that we will merely give an account of the character of the rocks, the grouping of the fundamental rocks advocated by Dr. Callaway[*] and by Professor Blake,[†] and the descriptions and arguments which they have adduced in support of their conclusions.

	A	*B*
Longmyndian Red Sandstone Series . . .	5	4
Longmyndian Flagstone and Shale Series . .	4	2
Uriconian Lavas and Ashes	3	3
Rushton Schists	1 & 2	1 ?
Primrose Hill Gneiss		3 ?

In this table *A* represents the order adopted by Dr. Callaway, *B* that of Professor Blake.

The Rushton Schists.

These rocks are exposed near the village of that name and consist of micaceous schists containing much quartz, white mica, a green mineral, epidote, and sometimes garnets; they are foliated, often exhibit signs of crushing, and suggest to Prof. Bonney the characters of the newer gneisses of Scotland and the Alpine "*Schistes lustrés*" of Lory. It is possible that some of them are rocks like the Primrose Hill gneiss crushed *in sitú*, but Dr. Callaway,[‡] guided by the differences in mineral constitution, inclines to the belief that they form a distinct group. No pebbles of these rocks have hitherto been met with in the conglomerate of Charlton Hill and, although pebbles of quartz schist are quoted from the Longmynd conglomerates, Dr. Callaway is not struck by any resemblance between them and the Rushton schists. So far as the evidence of strike is of any value in so disturbed and faulted an area, it tends to agree better with that of the Primrose Hill gneiss than with that of any other rock; but as, within the Rushton area itself, the strike varies considerably we cannot lay very much stress on any argument derived from it.

* *Geol. Mag.*, Dec. 3, vol. i, 1884, p. 362, and *Quart. Journ. Geol Soc.*, vol. xlvii, 1891, p. 109.

† *Quart. Journ. Geol. Soc.*, vol. xlvi, 1890, p. 386.

‡ *Geol. Mag.*, Dec. 3, vol. i, 1884, p. 362.

The Uriconian Rocks.

To Dr. Callaway * we owe the identification and detailed description of these ancient rocks, and although Mr. Allport † had independently recognised the lithological character of the ancient pitchstones of Lea Rock and the Wrekin, Dr. Callaway was the first to settle their relationship to the fossil-bearing series and to describe them in detail.

Granitic Rocks.—At the North end of the Wrekin massif there is exposed at the *Ercal* quarry a mass of macrocrystalline acid rock which has been called granitoidite and eurite by Bonney‡ and Blake§ respectively. It appears to be faulted off the main mass of Wrekin rhyolite, but is in contact with a greenish felsite with pink porphyritic felspar crystals; this junction is supposed by Bonney to show that the latter is intrusive into the former, while Callaway supposes it to be a fault. The former supposition makes the felsite the newer rock, the latter leaves the relative dates undetermined; Prof. Blake on the other hand thinks the granitoid rock may be intrusive in the rhyolite.

Rocks which approach granite or diorite in composition but gneiss in structure are exposed also at *Primrose Hill* at the south-west extremity of the chain; and these are regarded as part of the Ercal granitic series by Callaway, while Blake supposes them to be either "Eurite" somewhat foliated, or else fragments of an older metamorphic series brought to the surface by an intrusive rock.

We have, thus, two views before us; either the granitic rock may be more ancient than the lavas to be immediately described, or it may be the plutonic representative of them, and constitute the material solidified in the "necks" from which they were discharged. The annexed section and plan (figs. 2 and 3), borrowed from Dr. Callaway's paper, will show his views with regard to the various constituents of the Wrekin massif.

Volcanic or Rhyolitic Group.—The main mass of the *Wrekin* is largely made up of a succession of flows of rhyolitic lava interbanded with sheets of agglomerate and ash of similar composition. The latter are well seen in the quarry at Lawrence Hill from which bombs and fragments of rhyolite may be collected, the former occur in the crags on the main mountain mass, are still better shown in the *Wrockwardine* massif, and are well exposed at the Lea Rock quarry. The rock at this locality is a green or purple rhyolite showing banded and spherulitic structures, the latter being often arranged in bands, giving rise to a very beautiful rock. Perlitic structure

* *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, p. 643, vol. xxxviii, 1882, p. 119, and vol. xlii, 1886, p 481.

† *Quart. Journ. Geol. Soc.*, vol. xxxiii, 1877, p. 449.

‡ *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, p. 662.

§ *Quart. Journ. Geol. Soc.*, vol. xlvi, 1890, p 386.

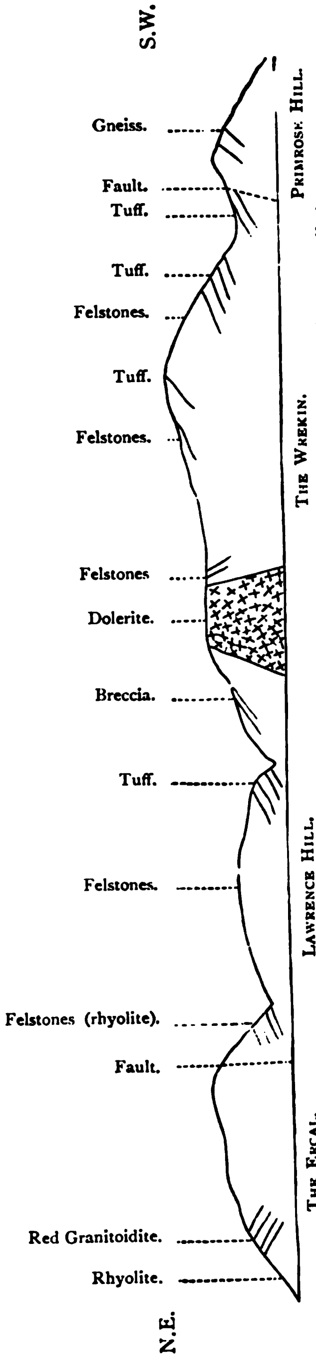

FIG. 2.—LONGITUDINAL SECTION OF THE WREKIN CHAIN.—*C. Callaway.* (Scale 2¼ in. to 1 mile.)

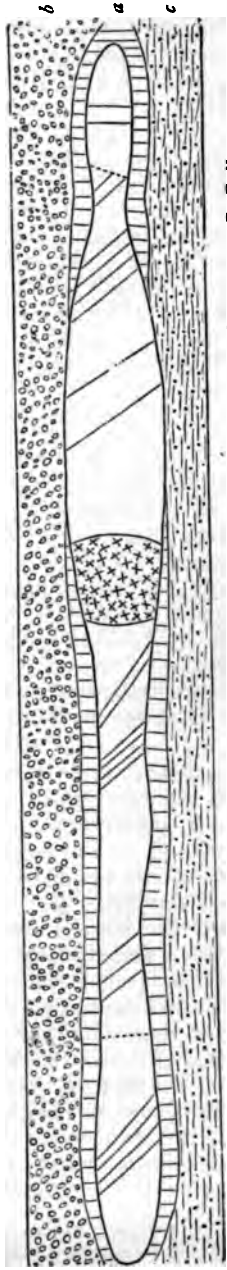

FIG. 3.—GROUND PLAN OF THE SAME, THE DIPS IN FIG. 2 BEING CONVERTED INTO STRIKES.—*C. Callaway.*

a Quartzite. *b* Hollybush [Comley] Sandstone. *c* Trias.

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is not at all uncommon and often occurs on a very large scale, giving rise to lithophyses in which the concentric cracks are infilled with silica and the centre is either hollow or filled with chalcedony or crystalline quartz. Both here and at the Wrekin the lava-flows are penetrated by dykes and bosses of basic rock. Sedimentary rocks rarely occur in the volcanic series of this part of the county, but at *Charlton Hill* there is a conglomerate which not only contains fragments of the rhyolites but also of a rock undistinguishable from the Wrekin granitoid. The accompanying section of Charlton Hill (fig. 4) is reprinted by Dr. Callaway's kind permission from his paper,* and shows the relationship of the different Uriconian rocks of that region. The andesitic lava links the section with other Uriconian rocks in the district, and the grits and conglomerates may be compared with some in the Wrekin area. The unconformable relation of the quartzite in this section will be noted by the reader.

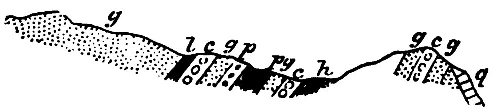

FIG. 4.—SECTION ACROSS CHARLTON HILL.—*C. Callaway.*

c	Conglomerate.	*l*	Andesitic lava.
g	Grit.	*h*	Hälleflinta.
p	Pebbly Grit.	*q*	Cambrian quartzite.
pg	Grit and pebbly grit.		

(Reprinted by permission from *The Quarterly Journal of the Geological Society*, vol. xlvii.)

Passing farther south we come upon the Uriconian masses of the *Church Stretton Hills*. Here we have a great complex of volcanic and sedimentary rocks, for details of which the reader must be referred to the original papers. It is sufficient for our purpose to note the general characters of the rocks in view of the controversy on their date to be subsequently referred to. According to the descriptions of Callaway and Blake the rocks of the Lawley and Caradoc consist of felspathic grits, felsites, and ashy shales, penetrated by innumerable dykes and sheets of basic rock. The section given below (fig. 5), and taken from Dr. Callaway's paper,† shows the relation of the rocks associated with the Uriconian of Little Caradoc to the overlying Cambrian strata.

Similar volcanic rocks occur on Helmeth, Hazler, and Hope Bowdler Hills, and expand towards the east over a great area in Cardington Hill, where a patch of granitoid rock likewise occurs. On Ragleth Hill the Uriconian grits and felspathic rocks are said to be separated from the Longmynd strata to

* *Quart. Journ. Geol. Soc.*, vol. xlvii, 1891, p. 116.
† *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, p. 657.

the west by a fault. The line of rocks is continued by isolated exposures, such as Warthill knoll, to the hills of Kington, in Radnorshire, while hornstones, ashy slates, and felspathic agglomerates are found in the same line at Lilleshall Hill to the north-east of the Wrekin.

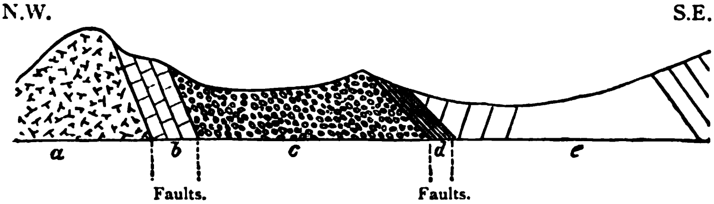

FIG. 5.—SECTION ACROSS LITTLE CARADOC AND VALLEY TO THE SOUTH EAST. (Length of Section about half a mile).—*C. Callaway.*

q Greenstone of Little Caradoc. *b* Quartzite. *c* Hollybush [Comley] Sandstone.
d Tremadoc (Shineton Shales). *e* Caradoc.

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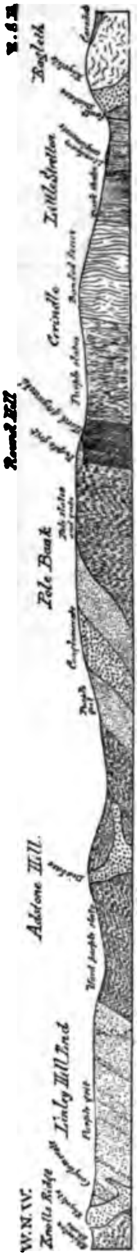
The Pre-Cambrian age of these rocks rests on the evidence of infra-position to the Cambrian strata, supported by that of included fragments in Ordovician and Cambrian beds. The strike of these rocks is everywhere E. and W., as shown in Dr. Callaway's map,* while the Longmyndian and Caradoc rocks all strike N.E. and S.W. Pebbles of the granitic rocks occur in the conglomerate of Charlton Hill, supposed to be of Uriconian age by Dr. Callaway, while pebbles of rhyolite occur in the same conglomerate, in the Longmyndian conglomerate of Haughmond Hill, and in the strata of the Longmynd proper, both in the upper Red series and the lower Grey division, to which reference will shortly be made.† Further reference to the age of these rocks is postponed until the Longmynd rocks have been dealt with.

A line of knolls of Uriconian rock was identified by Dr. Callaway on the *west of the Longmynd*, of which the most important is the group near Pontesford Hill.‡ This abrupt hill is singularly like the Wrekin in general shape, and contains banded and spherulitic rhyolites and dolerites. At Lyd's Hole these rhyolites are followed closely by the Purple Sandstones and Shales of the Longmyndian, and west of Ratcliff there is a conglomerate full of pebbles of quartzite and purple rhyolite, with green slate and mica schist; a second conglomerate with larger pebbles occurs more easterly in the series. Other masses of igneous rock at Gatton Lodge, Knolls, Cold Hill, Chittol, Knolls Wood, and Oldmores Wood, which present corresponding features, are referred by Dr. Callaway to the Uriconian.

* *Quart. Journ. Geol. Soc.*, vol xlvii, 1891, p. 120.
† *Quart Journ. Geol. Soc*, vol. xlii, 1886, p. 481.
‡ *Quart. Journ. Geol. Soc*, vol. xxxviii, 1882, p. 119.



["Cambrian."] (Scale, 1 inch = 1 mile.) ["Upper Monian."]

FIG. 6.—GENERAL SECTION ACROSS THE SOUTHERN PART OF THE LONGMYND AND THE VOLCANIC HILLS.—*J. F. Blake.*
(Reprinted by permission from the *Quarterly Journal of the Geological Society*, vol. xlvi.)

THE ROCKS OF THE LONGMYND.

The barren strata of the upland district of the Longmynd have been estimated at 23,000 feet in thickness. Geographically, as well as geologically, they arrange themselves in two divisions, namely, a *Western Longmynd Series* of Red Sandstones and Conglomerates, calling to mind the Torridon Sandstones of the N.W. of Scotland, and an *Eastern Longmynd Series* of grey shales and flagstones, typically developed in the hills near Church Stretton. Murchison and his followers regarded the whole of these Longmynd strata as *Cambrian*, Dr. Callaway unites them all under the title of the *Longmyndian*, while Prof. Blake assigns the Western Series to the Lower Cambrian, and the Eastern Series to a pre-Cambrian system, the *Monian.*

Although an account of the order of succession in the Longmynd was given by Murchison, that given by Prof. Blake is rather fuller and more minute, so that it will be convenient to quote the description of his sub-divisions in the account of these strata. The general dip of the rocks in these hills is steep, and towards the north of west, the successive bands striking from N.N.E. to S.S.W. The oldest rocks are, therefore, met with to the east, where the Lower division is on the whole slaty, while the Higher division to the west is mostly made up of grits and conglomerates. Prof. Blake's divisions are given in descending order, and the accompanying section (Fig. 6) is reprinted from his paper* by his kindly permission.

Western or Red Longmynd Series ("Lower Cambrian" of Blake).	10. Grit. 9. Hard Purple Slate. 8. Grit. 7. Conglomerate. 6. Grit.
Eastern or Grey Longmynd Series ("Upper Monian" of Blake.	5. Purple Slates and Grits. 4. Hard Greywacke. 3. Purple Slate. 2. Banded Group. 1. Dark Thin Shale.

* *Quart. Journ. Geol. Soc.*, vol. xlvi, 1890, p. 386.

Western Longmyndian or "Upper Monian Rocks."—1. The lowest beds are dark, thin shales, usually very soft and much contorted, with slip-strain cleavage; very beautifully shown in the quarries at Church Stretton.

2. Hard greywackes, with pale slates, well banded; seen in Minton Beach.

3. Soft purple slate, with very few grit bands.

4. Hard, often micaceous greywacke; shown in the Carding Mill Glen, where it contains some bands of slate.

5. Pale greenish slate, weathering purple.

The annelid markings and rain spots prove that the older rocks are towards the east, and that the succession rises westward: if there are no breaks or inversions the thickness is calculated at about 3 miles. It is in these rocks that Salter found the impressions referred by him to *Palæopyge* and *Dikellocephalus*, which are almost certainly the remains of organisms, but of what kind it is impossible to say; from them, too, Professor Blake records the occurrence of *Lingulæ*.

Eastern Longmyndian or "Lower Cambrian Series."—The Upper Longmyndian rocks, according to Professor Blake, begin with (1) a bed of grit, containing small angular masses of purple slate, about half-inch in diameter. This is followed by a large mass of conglomerate (2), forming a very striking feature at the south of the district, and seen again at Haughmond Hill, where it contains fragments of purple rhyolite; its main constituents, however, are quartz and quartzite pebbles. (3) Then comes another mass of purple grit, not showing clear stratification, and penetrated by dykes of dolerite, followed by (4) purple slate, whose outcrop occupies 2 miles of nearly vertical strata, passing through Ventnor and Ratlinghope: this band narrows towards the north, and is at last reduced to a quarter of a mile. (5) Another band of purple grit like the preceding, containing sporadic bands of conglomerate, completes the section. The dip is everywhere towards the west, except at Lyd's Hole, where these beds dip easterly at 60°, while in the south of the district the dip of the upper rocks is as low as 20° towards the west.

Relationships of the two Series.—The junction between these two great groups of strata in the Longmynd area is regarded by Professor Blake as an unconformity, and in support of this view he cites the irregular junction of the grits with the beds below, the presence of outliers of the former on the latter as at Narnell's Rock, the possible derivation of fragments in the grit from the slates below, and some other points derived from the volcanic hills or "Uriconian" rocks. The western so-called "Uriconian" rocks of Dr. Callaway, from Pontesford Hill to Linley, he regards as intrusive into the Cambrian grits; the eastern Uriconian rocks as also extrusive through the "Monian" slates (which are altered at the junction), and poured out into lava streams on the eastern side. The grits and conglomerates with rhyolite fragments met with in the Stretton Hills, in the Wrekin, and at Charlton Hill he correlates with the basal "Cambrian" grits of the Longmyndian and rather inclines to place the volcanic rocks at the base of his "Cambrian" system. The succession of events that he derives from his observations is therefore the following:—

1. Rushton Schists possibly "Middle Monian."
2. Deposition of "Upper Monian" of the Eastern Longmynd.
3. Irruption and eruption of Uriconian rocks.
4. Deposition of "Cambrian" strata of Western Longmynd and the volcanic hills.
5. Deposition of Quartzite and *Olenellus* strata.

Dr. Callaway finds himself unable to assent to these conclusions of Professor Blake, on the following grounds* :—

1. He cannot agree to the extrusion of the Uriconian rocks through the slates at the east of the Longmynd.
2. Neither Dr. Callaway, nor Prof. Bonney on microscopic grounds, can admit the contact alteration of Longmynd grit at Pontesford Hill, demanded by Prof. Blake's theory, while that grit is itself made of volcanic fragments.
3. He can find no evidence for visible unconformity at Narnell's rock, but thinks the grit and slate there graduate into one another by alternation.
4. Volcanic pebbles occur (rarely however) in the "Monian" division of the Longmyndian as well as in the higher rocks.
5. Professor Blake's "Cambrian" grits of Cardington, Caer Caradoc, and Charlton Hill seem to be interbedded with the volcanic series, and not to overly them unconformably.
6. He lays great stress on the fact, which he illustrates by a map, that the Uriconian rocks strike E. and W., while the Longmyndian rocks elsewhere strike N.N.E. and S.S.W.
7. He concludes by pointing out that the rocks of the volcanic hills are in their method of deposit irregular, massive, and lenticular, while the Longmynd rocks result from regular and even sedimentation.

IV. THE CAMBRIAN SYSTEM.

Coming next to the rocks which can be demonstrated upon fossil evidence to belong to the Cambrian system, we find that they are met with to the east and west of the Wrekin and in an area stretching from this mountain to Evenwood Common. Another strip occurs east of the Lawley, and a third west of the Stiper Stones. The Cambrian system of the Wrekin and Caradoc areas consists of three lithological members:

3. Shineton Shales
2. Comley Sandstones
1. Wrekin Quartzite.

* *Quart. Journ. Geol. Soc.*, vol. xlvii, 1891, p. 109.

THE QUARTZITE.

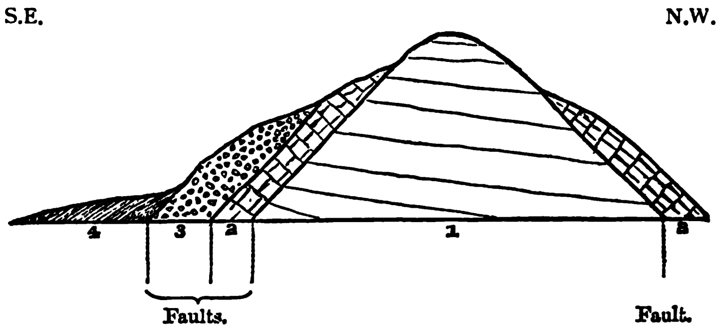
The Cambrian Quartzite is separated from the Uriconian rocks at the Wrekin by an unconformability, as is indicated by the presence of fragments of rhyolite in the basal beds, although the actual present junction line in this area may possibly be a fault. It occurs it contact with the Uriconian rocks, also along the Caradoc Chain, but is absent on the west of the Longmynd.

The only fossil hitherto obtained from it is a worm-burrow quoted by Dr. Callaway.* This rock is the "altered Caradoc" of Murchison and the Survey, and must not be confused with the Ordovician or Arenig quartzite of the Stiper Stones.

THE COMLEY SANDSTONE.

The Quartzite graduates upwards by diminution of acid materials and increase of basic matter and glauconite, into the Hollybush Sandstone, so called by Dr. Callaway † from its resemblance in physical character and stratigraphical position to that of Hollybush in the Malvern Hills. He quotes from it an indeterminable trilobite and *Kutorgina cingulata*, Billings, and remarks that a considerable area of this rock is exposed near Lilleshall Hill.

The relations of these rocks to one another and to the Shineton Shales are indicated by Dr. Callaway's section (Fig. 7).



(Scale about 8 inches = 1 mile.)

FIG. 7.—SECTION ACROSS THE WREKIN, NORTH-EAST END.—*C. Callaway.*

1. Bedded Precambrian volcanic tuff, dipping north.
2. Quartzite (probably Precambrian).
3. Hollybush [Comley] Sandstone.
4. Shineton Shales (Tremadoc).

(Reprinted by permission from the *Quarterly Journal of the Geological Society*, vol. xxxiv.)

* *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, p. 763.
† *Quart. Journ. Geol. Soc.*, vol. xxxiii, 1877, p. 652.

The lower Cambrian age of this Sandstone was originally maintained by Dr. Callaway, and in 1885 Professor Lapworth collected fragments of *Olenellus* from the Hollybush Sandstone at Comley in the gap between the Lawley and Little Caradoc. These occurred in the band of limestone which had previously yielded to Dr. Callaway some indeterminable trilobites.* In 1888 Lapworth was able to announce† the discovery of a definite zone containing *O. Callavei*, Lapw. In 1891 he described and figured‡ this species, and announced the detection in a higher zone by Mr. T. Groom of a recognisable *Paradoxides*, fragments of which had already been met with near Neves Castle. He also gave a description of the subdivisions of these fossiliferous sandstones, for which he suggested a local name, the *Comley Sandstone*, for the sake of convenience. The lowest beds of the Sandstones resting on the quartzite are olive green felspathic flags, grits, and concretionary shales, above which comes a highly calcareous band of bright purplish-red calcareous sandstone, or sandy limestone, in which are found *Olenellus Callavei*, Lapw., *Kutorgina cingulata*, Billings, *Linnarssonia sagittalis*, Walcott, *Hyolithellus* (cf. *H. micans*, Walcott), and *Elliptocephalus*, sp.

Over this come conglomerates and gritty and quartzose strata containing abundant fragments of igneous rocks, concretions of carbonate of copper, limestone-bands, and limy nodules, and these in turn pass into flaggy shales and quartzose grits. The limestone is distinguished by *Paradoxides Groomii*, Lapw., *Ptychoparia*, *Obolella*, and *Protospongia*, which may be collected at Comley, and at Neves Castle near the Wrekin.

THE SHINETON SHALES.

3. The Comley Sandstones are succeeded at the Wrekin, the Lawley, and Cardington by the Shineton Shales. They are also exposed in a band, many miles in length, at the east side of the Stiper Stones, under which they dip. They are generally "dark blue, weathering to olive and yellow . . . micaceous, thin bedded, soft and rather fissile." § Occasionally calcareous nodules occur, and the top of the series is more arenaceous. The accompanying section (Fig. 8), inserted by Dr. Callaway's permission, shows the relationship of the shales to the overlying Caradoc Sandstone, but the apparent conformity between them is only local and deceptive.

Shales with *Dictyonema sociale*, Salt., are seen in Mary Dingle, Back Dingle, etc., but the highest and most fossiliferous strata are to be seen in Shineton (Belswardine) Brook.

* *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, p. 759.

† *Geol. Mag.*, Dec. 3, vol. v, 1888, p. 484.

‡ *Geol. Mag.*, Dec. 3, vol. viii, 1891, p. 529.

§ *Quart. Journ. Geol. Soc.*, vol. xxxiii, 1877, p. 657.

Here occur—

Conocoryphe monile, Salt.
Olenus Salteri, Call.
Olenus triarthrus, Call.
Agnostus dux, Call.
Lingulella Nicholsoni, Call.
Obolella Sabrinæ, Call.
Theca.
Primitia.
Asaphellus Homfrayi, Salt.
Platypeltis Croftii, Call.
Conophrys Salopiensis, Call.
Lichapyge cuspidata, Call.
Macrocystella Mariæ, Call.
Dendrograptus.

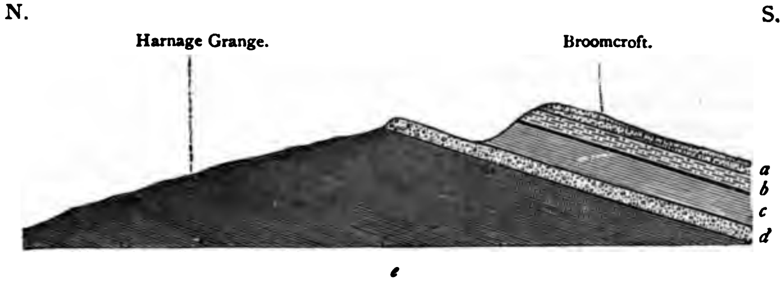


FIG. 8.—SECTION THROUGH HARNAGE GRANGE AND BROOMCROFT.—*C. Callaway.*

a. May-Hill Sandstone.
b. Chatwall Sandstone.
c. Harnage Shales.
d. Hoar-Edge Grits.
e. Shineton Shale.

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Similar *Dictyonema*-bearing shales occur in the deep hollow east of the Lawley and elsewhere, and Murchison and the Survey officers correctly placed on about the same horizon the shales with *Lingula* east of the Stiper Stones, which Dr. Callaway identifies with the Shineton Shales. These Shineton Shales are about 1,500 feet thick, and compare broadly with the *Dictyonema* shales which overlie the *Olenus* shales of Malvern (a division, the fossils of which have not been hitherto detected in Shropshire). They represent also the shales with *D. sociale* found at Pedwardine, near Brampton Bryan, described by Murchison* and Lightbody,† and they are doubtless of Tremadoc or Upper Lingula Flag age.

V. THE ORDOVICIAN SYSTEM.

PRELIMINARY NOTE.

The rocks of this system come to the surface in three distinct districts, namely;—(1) The Shelve District; (2) The Caradoc District; and (3) the District of the Breidden Hills.

* *Siluria*, ed. 5, 1872, p. 45.
† *Geologist*, vol. 3, 1860, p. 462.

The Shelve District—This is the largest area, and descriptions of it will be found in Murchison's *Silurian System* and in the successive editions of his *Siluria*; in Mr. G. H. Morton's *Geology of Shelve*; and in Professor Lapworth's *Preliminary Note on the Ordovician Rocks of Shropshire.*

Murchison's* account of the Shelve rocks is essentially lithological. He places the whole of them in his "Llandeilo Division." He pays especial attention to the various types of associated igneous rocks, both bedded and intrusive, and he gives an excellent description of the mining ground and of the remarkable Quartzite ridge of the Stiper Stones. In the successive editions of his *Siluria*, three divisions are recognised by him in the Shelve rocks; (1) A lower division, including the Stiper Stones, regarded as the equivalent of the Lingula flags and Tremadoc rocks of North Wales; (2) A middle division called Lower Llandeilo; and (3) An upper division called Upper Llandeilo. He illustrates his account in *Siluria* by a copy of the Survey section through the ground.

Mr. G. H. Morton† added largely to our knowledge of the rocks and fossils of the district, and included an excellent account of some of the mineral veins.

Professor Lapworth‡ published a general table of the rocks of the district, placing the Stiper Stones at the base of the Ordovician, and arranging the strata above in the three successive Series of Shelve, Meadowtown, and Chirbury, which he paralleled with the Arenig, Llandeilo, and Bala series of other districts. He also divided each Series into various subordinate members.

The Caradoc District.—Murchison's original description of the Caradoc District in his *Silurian System* made the rocks of this district the type of his *Caradoc Sandstone*, in which however he included the strata subsequently separated as Llandovery.

This original classification is greatly improved by him in the successive editions of *Siluria*, in which the discoveries made by the officers of the Survey became incorporated. But the most important paper§ issued upon the Ordovician rocks of the Caradoc region is that of Salter and Aveline, which followed upon Sedgwick's suggestion of the general unconformability between Murchison's "Lower" and "Upper Silurian." In this paper the fossiliferous Caradoc rocks are separated into five lithological groups.

The lowest of these groups has since been shown by Dr. Callaway to be of Upper Cambrian age; but in all other respects the paper of Salter and Aveline is still our standard work upon the "Caradoc Sandstone."

* *The Silurian System*, 1839. *Siluria*, 1854—1872.
† *Proc. Liverpool Geol. Soc.*, vol. x, 1854, p. 62.
‡ *Geol. Mag*, Dec. 3, vol. iv, 1887, p. 78.
§ *Quart. Journ. Geol. Soc.*, vol. x, 1854, p. 62.

The Ordovician rocks of the Caradoc area have been recognised almost from the first as the general equivalents of the Bala beds of North Wales.

The Breidden District.—The rocks of the Breidden District were noticed by Murchison somewhat in detail, both in the *Silurian System* (p. 290), and in *Siluria*; and the fact that they contain both contemporaneous and intrusive igneous rocks was fully recognised by him. In the year 1886 Mr. Watts* published an account of his own work among these rocks.

The Ordovician Rocks of Shropshire in General.—Among these Ordovician rocks of Shropshire the work of Murchison led to the recognition of their true position *below* the great mud-stone and limestone series of his "Upper Silurian" typified by the Wenlock and Ludlow formations, and *above* the barren "Cambrian" system as typified by the rocks of the Longmynd. The mapping of H.M. Geological Surveyors added largely to the details worked out by Murchison, and established the universal unconformity in Shropshire between Murchison's "Lower" and "Upper Silurian" systems. The recent discovery of the *Olenellus*, *Paradoxides*, and *Olenus* zones within the original *Lower Silurian* of Shropshire is of extreme interest, as it brings the Lower Palæozoic strata of this South Shropshire region into harmony with those of other lands. The true, or fossiliferous, *Cambrian System* (or *Zone Primordiale*) thus falls naturally into the place originally assigned to it by the contemporaries of Murchison in Bohemia, Scandinavia, America, etc., and by the officers of the Geological Survey under him, as the lower half of the *Lower Silurian*; while its upper half is that system now known to us as the *Ordovician*. According to Professor Lapworth the Ordovician is itself arranged naturally into series, groups, and local zones, which admit of being more or less accurately paralleled with their equivalents in Britain and in other parts of the world. The detailed results of Lapworth remain as yet unpublished, but his coloured six-inch maps of the whole of the Ordovician ground were exhibited at the International Geological Congress in London in 1888, and are well known to those geologists, British and Foreign, who have visited the district in his company.

The groups into which the Ordovician strata may be divided are shown in descending order in the annexed table (p. 316), the divisions of Murchison, Salter, and Aveline, being placed alongside for purposes of comparison.

It will be seen from this table that while all three divisions—Arenig, Llandeilo, and Bala—of the Ordovician rocks are present in conformable sequence in the district west of the Longmynd, only the Bala (or Caradoc) series has been recognised to the east, and it rests with a striking unconformity on Longmyndian, Uriconian, and Cambrian strata. In the latter area higher

* *Quart. Journ. Geol. Soc.*, vol. xli, 1885, p. 532.

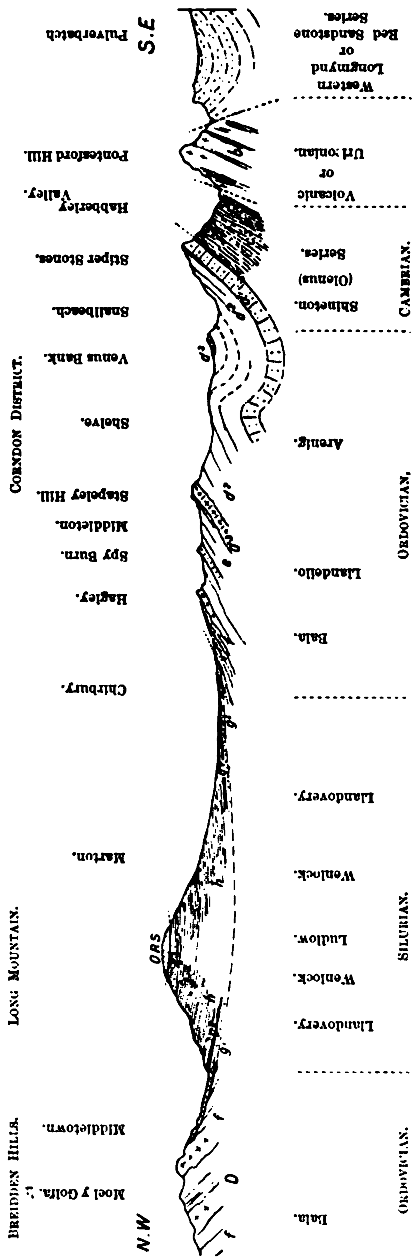

Fig. 9.—Sketch Section across Western Shropshire from the Breidden Hills to the Longmynd.

Figures 9 and 10 form one continuous section; the right hand side of Fig. 9 joins the left hand side of Fig. 10. The index to strata printed below Fig. 10 refers to the whole section.

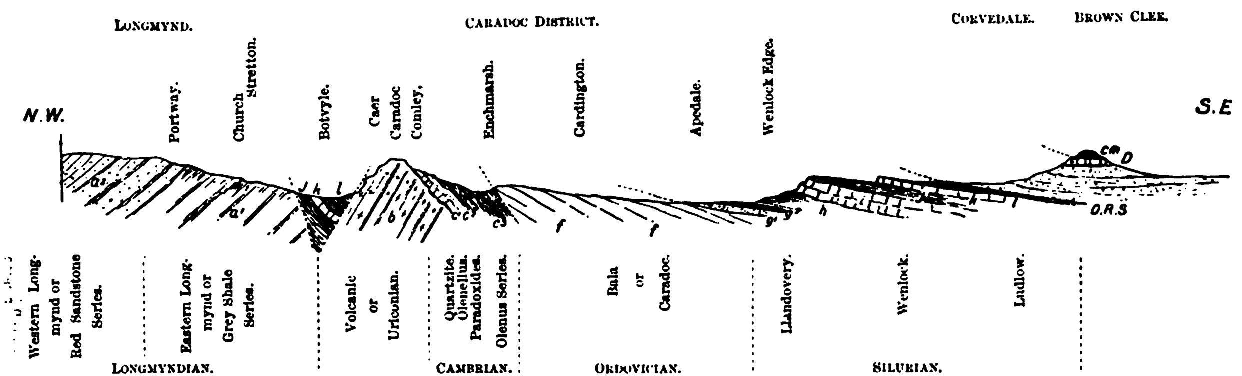

FIG. 10.—SKETCH SECTION ACROSS CENTRAL SHROPSHIRE FROM THE LONGMYND TO THE BROWN CLEE HILL.

a^1. Eastern Longmynd or Grey Shale Series.
a^2. Western Longmynd or Red Sandstone Series.
b. Uriconian Volcanic Series.
c^1. Quartzite.
c^2. Comley Sandstone.
c^3. Shineton Shales.
d^1. Stiper Group. } Arenig or Shelve Series.
d^2. Ladywell — }
d^3. Stapeley — }
e. Llandeilo or Meadowtown Series.
f. Bala, Caradoc, or Chirbury Series.
g^1. Upper Llandovery Sandstone, Conglomerate, and Limestone.
g^2. Purple Shale.
h. Wenlock Shale.
i. Wenlock Limestone.
j. Lower Ludlow Rocks.
k. Aymestry Limestone. Upper Ludlow Rocks.
O.R.S.=Old Red Sandstone.
C.M.=Coal Measures.
D.=Dolerite.

The Ordovician Rocks of Central Shropshire.

	Caradoc.	Shelve.	Caradoc.	Shelve.
Series.	Lapworth.*		Salter and Aveline.†	Murchison.‡
Bala or Chirbury Series.	Onny *Trinucleus* Shales ... Acton Scott Beds ... ... Longville Flags ... ... Chatwall and Soudley Sandstones ... ... Harnage Shales ... ... Hoar Edge Grit and Limestone	Marrington Group ... Whittery Shale Whittery Ash Hagley Shale Hagley Ash Spy Wood Group: Aldress Shale Spy Wood Grit	*Trinucleus* Shales ... Longville Flags ... Chatwall Sandstone ... Hoar Edge Grits ...	1. Schist and Sandstone. 2. Felspathic Sandstone and 3. Concretionary Felspar Rock. 4. Flags and Shales. 5. Stratified Trap. 6. Shale and Trap-tuf.
Llandeilo or Meadowtown Series.		Rorrington Flags ... ... Middleton Calcareous Series ... ... Weston Group: Grit ... ... Shale ... ... Grit ... ... Shale		8. Black Shale and true Llandeilo Flags. . . 9. Stratified Felspar Rock. 10. Volcanic Grit, dirty green 11. The same, but more crystalline. 12. Black Shale and Sandstone.
Arenig or Shelve Series.		Stapeley Ash ... ... Hope Shales ... ... Mytton Flags ... ... Stiper Quartzite		Volcanic Grits and Ashes. Grey Flagstones, etc. Siliceous Grits.

* *Geol. Mag.*, Dec. 3, vol. iv, 1887, pp. 78—80.
† *Quart. Journ. Geol. Soc.*, vol. x, 1854, p. 64.
‡ *Siluria*, Ed. 5, 1872, pp. 66, 67, and pp. 38, 47, 49; *Silurian System*, 1839, pp. 269—271.

members of the Bala sequence are to be seen than in the former. At the Breiddens neither base nor summit of the Ordovician strata is visible, the former owing to the Severn alluvium and an anticline or fault, the latter to the Silurian overlap. The broad general structure of all three Ordovician areas can be understood by the inspection of the section across Central Shropshire (Figs. 9 and 10). We have only space to devote a few words to the description of the most salient points of each group.

THE SHELVE OR CORNDON DISTRICT.

The Shelve or Arenig Series.—The *Stiper Stones Quartzite* consists of well-rounded grains of quartz, with new growth of silica in optical continuity with that of the original grains; the only fossils hitherto described are worm-burrows and doubtful traces of *Lingulæ*. It stands up in a wall-like ridge several miles in length, and crags like the Devil's Chair and Cranberry Rock jut out on its course.

The *Ladywell Group* is better treated of as two distinct members—those of Mytton and Hope.

The *Mytton Group* consists of massive ribs of grit and flags interbedded with shales, which are well displayed at Mytton Dingle and Perkin's Beach. It forms the principal lead and zinc mining ground, and yields *Ogygia Selwynii*, Salt., *Theca simplex*, Salt., and *Ribiera complanata*, Salt., throughout, while in the upper part, near Shelve Church, is a band containing *Euomphalus Corndensis*, Sow., and various forms of *Dichograptidæ*.*

The succeeding *Hope Shale Group* ranges over much of the low ground of the region, is interbanded with a few ash-beds (*vide* Fig. 11), and contains many fossils, *Didymograptus Murchisoni*, Beck, being occasionally met with.

The *Stapeley Ashes* of Stapeley Hill are roughly the equivalent of the great Arenig volcanic rocks of North Wales, and are andesitic breccias and ashes evidently deposited in water, as the frequent interbanding with shales and the occasional fossils plainly show. The latter are found in the ash of Stapeley Hill itself and at Nind, Yr Ynys, and Tasgar in the associated ashy shales, which are shown below the ash-beds in Plate viii. A.

They always form important hills, and as the Arenig strata are folded into a syncline (of which one limb is the Ritton Castle and Cefn Gwynnlle ridge and the other the line from Round Hill to Berth House), and a corresponding anticline over Shelve Hill (of which the range from Bromlow Callow to Todleth is the western limb), there are three parallel ridges formed by this group (*vide* Figs. 9 and 10). The map, moreover, and the photograph (Plate viii. B) show that on a smaller scale the strata are also much contorted.

* *Quart. Journ. Geol. Soc.*, vol. xxxi, 1875, p. 636; *Ann. Mag. Nat. Hist.*, ser. 5, vol. iv, 1879, p. 333.

Beds of lava occur to the south, especially at Symond's Castle, Todleth, the Roundtain, and Llanfawr. These are augite and hypersthene andesites, usually with porphyritic crystals of felspar and occasionally with porphyritic groups of augite and hypersthene. The Stapeley ridges are also more or less broken by intrusive rocks which will be dealt with later on. Lists of fossils from the Shelve series are given by Morton in the work already cited and in the catalogue of Cambrian and Silurian fossils in the Jermyn Street Museum.

The Meadowtown or Llandeilo Series.—The *Weston Group*, named after the village of Priest Weston, is a varied one chiefly of shales interrupted by two massive beds of volcanic grit or greywacke which are well described by Murchison. These form marked ridges in the centre of the district, dying down as the rock passes towards the north and south. Fossils are rare, but *Ogygia Corndensis*, Murch., may be found.

The *Middleton Group* begins with shales and flags, in which *Didymograptus Murchisoni*, Beck, and *Orthis testudinaria*, Dalm., occur. These pass up into the *Ogygia* Flags and limestones of Middleton Church and Meadowtown, so well known from the abundance of *Ogygia Buchii*, Brongn., *Asaphus tyrannus*, Murch., *Trinucleus Lloydii*, Murch., sponge spicules, and brachiopods which they yield. They form a ridge less marked than those already described, but the strata are easily recognisable from Betton Ridge to Spy Wood and beyond.

6. The *Rorrington Flags* are intensely black mudstones yielding graptolites, which include *Cœnograptus gracilis*, Hall, and *Leptograptus flaccidus*, Hall. They are probably the "typical black shales" referred to by Murchison. . . . They pass up locally by alternations into the bed which forms the base of the Bala series.

The Chirbury or Bala Series.—The *Spy Wood Group* consists of a set of calcareous grits and flags (the Spy Wood Grit), from which brachiopods, trilobites, and graptolites may be collected, and in which *Beyrichia complicata*, Salt., occurs in extraordinary abundance, passing up into

The *Aldress Graptolitic Shale* with rare fossils except graptolites and marked by certain zones rich in specimens of *Dictyonema*.

The Marrington Group contains several stages, of which the following are the most important. They (together with all the beds from the Middleton limestones) may be seen in the Spy Wood section, and its continuation in the valley of the River Camlad at Marrington Dingle.

The Hagley andesitic *Ash*.

The Hagley Shales with occasional ash bands.

The Whittery Ash, splendidly exposed in the Whittery and Walk mill quarries (figured by Murchison), consists of andesitic and rhyolitic breccias and conglomerates, fine ashes with curious spherulitic or pisolitic structures, and bands of shale often fossiliferous. These beds often show the structure described as ripple marking; and slabs with rippled surfaces, many square yards in area, were formerly exposed in Whittery Bridge quarry, but have now been destroyed by the frost.

The Whittery Shales, rarely yielding fossils, form the ground between Marrington and Chirbury, where they (the highest Bala rocks of the district) are unconformably covered by the Llandovery strata which pass under the rest of the Silurian sequence of the Long Mountain.

CARADOC DISTRICT.

In the Caradoc District the divisions established by Salter and Aveline are likely to stand, with one exception. They unfortunately confused the Shineton Shales with those of Harnage, a very natural mistake owing to the extraordinary complication of the district about Harnage. This has been set right by Dr. Callaway, who first placed the Harnage Shales in their true position above the Hoar Edge Grit, and separated the Shineton Shales below as an older group belonging to the Cambrian System. The correlation of the divisions of the Caradoc rocks with the Bala sequence of the Shelve and Chirbury region as interpreted by Lapworth will be understood by reference to the table already given.

Caradoc or Bala Series.—*The Hoar Edge Grits* which form the base of the Bala in the Caradoc District are conglomerates, grits and bastard limestones, forming a ridge from Hoar Edge and Evenwood Common (Shadewell Coppice) to Caer Caradoc and again from Hope Bowdler to Horderley and Corston. At Hope Bowdler they are seen to rest unconformably on the Volcanic Rocks called Uriconian and to contain included fragments of them. They contain *Calymene Blumenbachii*, Brongn, *Trinucleus concentricus*, Eaton, *Orthis flabellulum*, Sow., *O. vespertilio*, Sow., *O. testudinaria*, Dalm, *Strophomena expansa*, Sow., *Orthis spiriferoides*, McCoy, *Stenopora fibrosa*, Goldf; and many of the same fossils (according to Lapworth) can be collected from calcareous bands in some of the volcanic rocks themselves.

The Harnage Shales which succeed are fine, thin-bedded, argillaceous shales not very fossiliferous but yielding graptolites occasionally. (In studying Salter's list* it must be remembered that Cambrian forms from the Shineton Shales are included by mistake.)

The freestones and building *Sandstones of Chatwall* and Soudley are fine and coarse-grained Sandstones, olive green and brown in colour, often streaked with purple and in thick beds.

* *Quart. Journ. Geol. Soc.*, vol. x, 1854, p. 64.

Orthis alternata, Sow., occurs freely, with *Homalonotus bisulcatus*, Salt., *Strophomena grandis*, Sow., *Glyptocrinus basalis*, McCoy, and *Leptæna sericea*, Sow.

The Cheney Longville Flags. A great series of thin-bedded flags with sandy shales succeeds, and in them the following fossils are fairly common: *Phacops conophthalmus*, Bœck., *Homalonotus bisulcatus*, Salt., *Tentaculites annulatus*, Schloth., while in the calcareous beds, which sometimes form an important limestone, *Trematis filosa* is found in abundance.

The Acton Scott Beds. Salter refers to the top beds, dark grey shales with bands of concretionary limestone, as of some importance in the Onny Section. They are however of much more consequence at Acton Scott, where they are associated with a peculiar igneous rock, the only one known in the Caradoc area. These may hence be called the Acton beds, and Salter quotes from them *Lichas laxatus*, McCoy, *Ampyx*, *Orthis Actoniæ*, Sow., *O. flabellulum*, Sow., and *Strophomena bipartita*, Salt. The abundance of corals may also be noted.

The Trinucleus or Onny Shales. The succeeding beds are rarely well seen, but they occur in the river at the Onny section and are thin-bedded sandy shales of a yellow, yellow-brown, or slate-colour, and contain abundance of *Trinucleus concentricus*, Eaton, also *Orthis elegantula*, Dalm., and *Leptæna sericea*, Sow. The very highest Bala beds are nowhere disclosed in Shropshire, as the Ordovician is invariably covered up unconformably by the local basement beds of the Silurian.

BREIDDEN DISTRICT.

Bala Series.—In the Breidden region the succession consists of beds of absolutely barren shale (*Criggion shales*), broken by one seam of grit and many sills of dolerite which have broken through the strata. At the top of the series come beds of rhyolitic ash, andesitic conglomerate and volcanic grits (*Bulthy ash*) with flows of hypersthene andesite lava on Moel-y-Golfa. Shales succeed, banded with ashy grits (*Bausley beds*) from which a series of fossils including *Trinucleus concentricus*, Eaton, *Climacograptus bicornis*, Hall, *C. Scharenbergi*, Lapw., *Cryptograptus tricornis*, Carr., *Diplograptus rugosus*, Emm., and *Leptograptus flaccidus*? Hall, with *Beyrichia complicata*, Salt., have been obtained. These and the general character of the rocks correspond very well with the Hagley Ash, and the barren Aldress mudstones beneath: and there can be no doubt that the rocks are of Bala age, and rather near the bottom of that series. The higher beds are concealed by a close overlap of *Pentamerus* sandstones. The structure of the Breidden range will be understood from the following section (fig. 11).

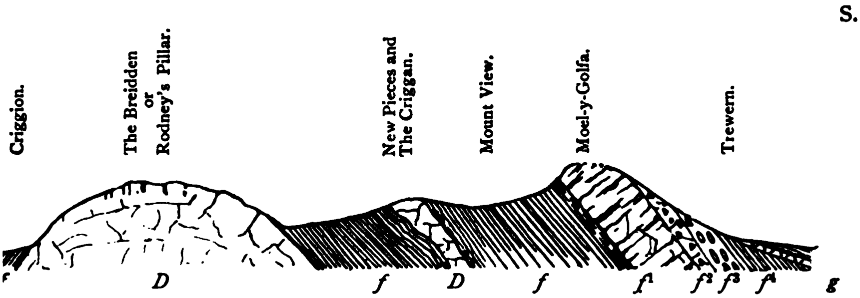

FIG. 11.—SECTION ACROSS THE BREIDDEN HILLS FROM CRIGGION TO TREWERN.

f. Criggion Shales (Bala). *f*¹. Andesitic Lava. *f*². Ash. *f*³. Conglomerate. (Bulthy Ashes.) *f*⁴. Bausley Shales. *g.* Pantamerus Sandstone and Purple Shales (Silurian). *D.* Dolerite.

VI. THE SILURIAN SYSTEM.

The rocks of this system, set in order and admirably described in their main divisions by Murchison, are typically developed in the region running from Wenlock to Ludlow and on to Aymestry, bounded on the west side by Apedale and on the east by Corvedale. As is well known they are divided into the following series in descending order:—

	WENLOCK AND LUDLOW AREA.	LONG MOUNTAIN.
SERIES.	GROUPS.	
Upper or LUDLOW Series.	Passage beds and Downton Sandstone. Upper Ludlow Rocks. Aymestry Limestone.	Passage Beds. *Cardiola* Beds. Hard Flags.
Middle or WENLOCK Series.	Lower Ludlow Rocks. Wenlock Limestone. Wenlock Shale.	Mudstones and Flags. Concretionary Mudstones.
Lower or LLANDOVERY Series.	Tarannon Shale. Upper Llandovery Rocks. (Lower Llandovery absent).	Purple Shales. Llandovery Sandstone.

LOWER OR LLANDOVERY SERIES.

Messrs. Salter and Aveline in 1854* gave us a classification of the Llandovery rocks of Shropshire, which holds good to the present day, and even applies to other parts of the county not studied by them. Their divisions in descending order are the following, the true Lower Llandovery rocks being absent from the area:—

3. Purple Shale, 200 to 400 feet.
2. *Pentamerus* Limestones.
1. Coarse Grits and Conglomerates.

* *Quart. Journ. Geol. Soc.*, vol. x, 1854, p. 62.

The *Basement Grit* is sometimes visible in force, when it gives rise to an abrupt escarpment like that at Gibbons Coppice, Kenley, and Church Preen; but at times it is overlapped by the second division, or more probably, as it is a shallow water shore deposit, thins out, Similar rocks are seen at intervals skirting the Longmynd at Minton and Norbury. They exist as outliers on the Ordovician rocks at Bogmine and Venus Bank, and occur to the north of the Shelve tract about Hope.

Amongst important fossils from this division quoted by Salter, the following may be mentioned :—

Calymene Blumenbachii, Brong.	*Atrypa reticularis*, Linn.
Illænus Barriensis, Murch.	*Atrypa marginalis*, Dalm.
Encrinurus punctatus, Brünnich.	*Rhynchonella decemplicata*, Sow.
Phacops Downingiæ, Murch.	*Pterinea retroflexa*, Wahl.
Orthis biforata, Schloth.	*Bellerophon trilobatus*, Sow.

The *Pentamerus Limestone*, which may be compared, in passing, to the Woolhope Limestone, as was in fact done by Sedgwick, is well seen at Morrells Wood, Belswardine, the Holly farm, Soudley, the Onny section, and Norbury, and to some extent to the north of the Shelve country. It is really a sandstone converted into a bastard limestone by abundance of fossils, especially *Pentamerus*.

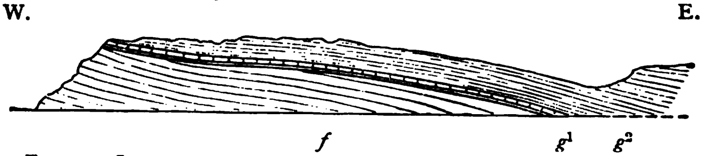

FIG. 12.—SECTION ON THE NORTH BANK OF THE RIVER ONNY AT CHENEY LONGVILLE FOOTBRIDGE, SHROPSHIRE; SHOWING THE PENTAMERUS-BEDS LYING UNCONFORMABLY ON THE OLDER STRATA.—*J. W. Salter.*

f. Trinucleus-shales (Llandeilo and Bala rocks).
*g*¹. Pentamerus-beds.
*g*². Purple Shales, followed by Wenlock Shale.

(Reprinted by permission from the *Quarterly Journal of the Geological Society*, vol. x.)

The section (fig. 12), borrowed from Salter,* shows the relation of the Limestone series to the *Trinucleus* shales of the Caradoc series below, but the exact junction is very difficult to make out, and can indeed only be exactly proved by finding rolled species of *Trinucleus* above, and uninjured specimens of the same trilobite below, the line of demarcation. Salter quotes the following amongst the fossils of this group :

Encrinurus punctatus, Brünnich.	*Pentamerus oblongus*, Sow.
Phacops caudatus, Brong.	*Pentamerus undatus*, Sow.
Atrypa hemisphærica, Sow.	*Stricklandinia lens*, Sow.
Orthis elegantula, Dalm.	*Leptæna transversalis*, Wahl.
Strophomena pecten Linn.	*Petraia bina*, Lonsd.
Strophomena compressa, Sow.	*Stenopora fibrosa*, Goldf.

* *Quart. Journ. Geol. Soc.*, vol. x, 1854, p. 70.

Sandstones on this horizon, but never sufficiently calcareous to form a limestone, occur round the Breidden inlier and are found about Middletown closely overlapping the Bala ash beds of that hill and of Moel-y-Golfa; they yield several of the fossils mentioned above. To the north they retreat further from the hills and let out from beneath rather higher beds of the Bala sequence. About the Hollies and at Norbury most characteristic masses of limestone with huge *Pentameri* (the so called Jacob-stones) are of very common occurrence, and abundant fossils have been obtained from the rocks of Bogmine and Venus Bank. A very interesting outlier of Llandovery rock occurs at Bank near Minsterley resting on the middle Arenig beds. It contains abundant shells and trilobites, especially *Encrinurus punctatus.* It was suggested by Ramsay in 1853 that "the outlying patches of Sandstone . . . on the high land near the Bogmine and Shelve are part of a Wenlock beach of somewhat later date than the conglomerates and limestones that underlie the Wenlock shale at lower levels on the south of the Longmynd," a very suggestive remark, which applies with even greater force to the patch at Bank where the fossils have a marked Wenlock facies and where species of *Pentamerus* are decidedly rare. The accompanying figure (Plate ix. A), taken from a photograph, shows the unconformable overlap of the Llandovery rocks on the Arenig rocks of the Hope group near Hope Rectory.

Following the *Pentamerus* beds of Salter come his *Purple Shales*, which vary from 200 to 400 feet in thickness. They are purple, red, and greenish shales, sometimes mottled and with a rather soapy texture. In some places they contain bands of fine blue micaceous sandstone, but they are usually almost unfossiliferous. Salter gives the following list:—

Beyrichia tuberculata, Salt.	*Strophomena pecten*, Linn.
Leptæna lævigata, Sow.	*Atrypa reticularis*, Linn.
L. transversalis, Wahl.	*Rhynchonella furcata*, Sow.
Orthis biloba, Linn.	*Petraia bina*, Lonsd.

These beds can be traced from the north of Buildwas, through Belswardine, Hughley, and Ticklerton, to the Onny, while similar but redder strata are found to the south of the Longmynd. Mr. Watts has discovered similar rocks in the low ground east of the Breiddens, while they also occur in their proper position between Hope and Minsterley. Indeed they probably form one of the most constant horizons in the Llandovery strata, for, wherever they are known they are hollowed out into marked wide, longitudinal, valleys, as at Morrells Wood and Leighton, at Belswardine, along Apedale, on both sides of the Onny, at Wagbeach, and along the Breiddens. It is almost certain they must be present in the great depression from Wotherton through Marton Pool to and beyond Worthen, and at other places along the Silurian boundary.

On the border of the Breiddens they contain only minute fossils, which in most cases are indeterminable, and no graptolite zones have been made out in them, although they almost certainly represent the Tarannon and Stockdale Shales.

MIDDLE OR WENLOCK SERIES.

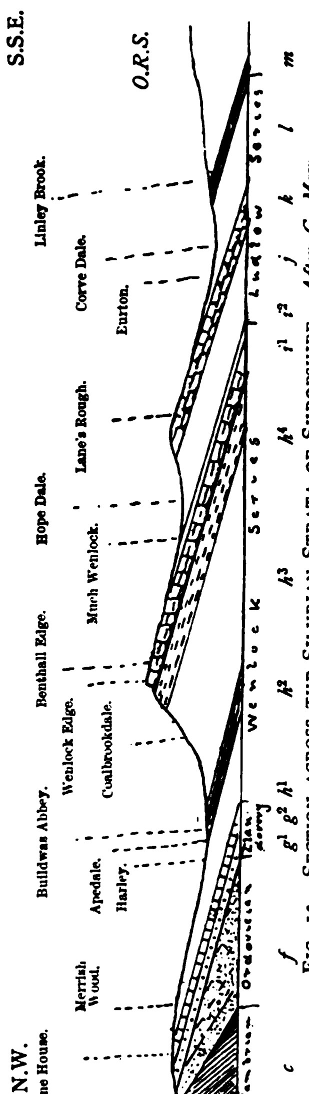

FIG. 13.—SECTION ACROSS THE SILURIAN STRATA OF SHROPSHIRE.—*After G. Maw.*

c Shineton Shales.
f Hoar Edge Grit.
g^1 Llandovery Conglomerate.
g^2 ——— Limestone.
h^1 Basement Beds } L. Wenlock Shale.
h^2 Buildwas Beds.
h^3 Coalbrookdale Beds } M Wenlock Shale.
h^4 Tickwood Beds } U Wenlock Shale.
i^1 Wenlock Limestone.
i^2 Shales over Limestone.
j Lower Ludlow.
k Aymestry Limestone.
l Upper Ludlow.
m Passage Beds.
O.R.S Old Red Sandstone.

Horizontal Scale, 1 inch = 1 mile.

The Localities are not all on the same line of Section.

The Wenlock Shale.—A brief description of this group is given by Salter, who, however, refers chiefly to its occurrence in the south of the district. The richly fossiliferous beds of Buildwas, however, yield an enormous number of fossils if the containing material is washed, a line of research initiated by Mr. J. F. Walker and Mr. Watts, but afterwards followed up with much zeal and success by Mr. George Maw and Dr. Davidson,* who washed several tons of the deposit and obtained thousands of specimens of brachiopods, polyzoa, and corals, and not a few trilobites. Mr. Maw subdivided the Wenlock series into the following stages in descending order, as illustrated by the section (fig. 13), copied with one alteration by his kind permission.

* *Geol. Mag.*, Dec. 2, vol. viii, 1881, pp. 1, 100, 145, 289.

6. Shales above Limestone; Hopedale and Much Wenlock.
5. Wenlock Limestone; Wenlock and Benthall Edge.
4. Upper Wenlock Shale or Tickwood beds; Coalbrookdale.
3. Middle Wenlock Shale or Coalbrookdale beds; 1,100 to 1,200 feet.
2. Buildwas Beds, of the Abbey; 80 to 100 feet.
1. Lower Wenlock Shale or *Basement beds*; 500 to 600 feet.

The total thickness of beds 1 to 4, or Wenlock shale proper, was estimated by Mr. Maw at 1,800 to 1,900 feet, and is of remarkably uniform character throughout, consisting of grey shale and mudstone, with concretionary lumps and occasionally bands of earthy limestone. The colour Mr. Maw states to be due "to the occurrence of iron in the state of protoxide, which may perhaps have resulted from the presence of the deoxidizing agency of organic matter." The shale generally appears to be barren of organic remains, except in the Buildwas and Tickwood divisions, but the immense number of fossils found in both these sub divisions, when they are favourably exposed, perhaps indicates that similarly abundant fossils might be obtained from the whole series if it were equally favourably situated; however, it is tolerably certain that graptolites are phenomenally rare in this deposit. The *Buildwas Beds* are exposed in a small cliff in the Severn opposite Buildwas Abbey, on the ledges of which at favourable states of the river an immense number of small brachiopods, chiefly *Orthis biloba*, Linn., *O. elegantula*, Dal., *O. elegantulina*, Dav., *O. Lewisii*, Dav., *O. rustica*, Sow., *O. hybrida*, Sow., are washed out by the gentle current of the river and may be collected by hundreds. A very interesting feature about the brachiopods obtained from these beds and those about to be described is their state of preservation in crystalline calcite, so that Mr. Norman Glass was able to display their internal structure, and the mode of attachment of the spiral arms in *Retzia*, *Atrypa*, *Glassia*, *Dayia*, was first made out in these specimens, while the two last-named new genera, in addition to early species of *Waldheima*, were first named from them.

Only the upper part of the *Coalbrookdale* Stage is at all well seen in the town of that name, where, as well as at Tickwood, it is succeeded by the uppermost division of the Shale. At the latter locality *Waldheimia Mawei*, Dav., *Retzia Salteri*, Dav., and *Retzia Bouchardi*, Dav., are fairly common, while at the cutting near Coalbrookdale Station, and at the curious exposure of the very top bed of the Wenlock shale at Lincoln Hill, great numbers of *Meristella tumida*, Dalm., *Spirifera plicatella*, Sow., and its varieties *S. crispa*, Linn., *S. elevata*, Dal., *Cyrtia exporrecta*, Wahl., *Nucleospira pisum*, Sow., *Atrypa reticularis*, Linn., *Pentamerus galeatus*, Dal., *P. linguifer*, Sow., with *Rhynchonella borealis*, Schl., are to be found. It is probably about this horizon, or low down in the Wenlock limestone, that an important bed of the otherwise uncommon *Atrypa marginalis*, Dal., occurs.

The top of the Buildwas beds is formed by "a remarkable cream-coloured clay resembling steatite in texture. The late Mr. David Forbes made . . . an analysis of these bands . . . and remarked on the smallness of the percentage of magnesia in the mineral which so closely resembles compounds which from their unctuous feel and external characters are usually considered to be highly magnesian."*

" Silica	45·48	
" Alumina	23·52	
" Ferrous oxide	1·76	
" Manganous oxide	0·07	
" Lime	6·22	11·10 Carbonate of Lime.
" Carbonic acid	4.88	
" Magnesia	1·44	
" Potash	2·15	
" Soda	0·54	
" Water	13·88	
	99·94 "	

It is important to notice that the outcrop of these clays passes through or above the point near Marnwood, where a very serious landslip occurred in 1773, on which occasion the Rev. John Fletcher, of Madeley, preached a sermon on the spot, concluding "that the God of Nature had shaken his providential iron rod over the submerged spot." He, however, does not appear to attribute the slip to the Walker's earth, but to the "wickedness of waggoners," and to those who "contrived to meet the bottomless pit by driving perpendicular ways towards the centre of the earth." Murchison had previously noticed the occurrence of similar landslips in connection with the "Walker's earth" of the Lower and Upper Ludlow strata, and many such are shown on his map in the Silurian System to occur in the hills west and south-west of Ludlow. He instances Palmer's Cairn, Brindgwood Chase, and Ferney Hall, in which cases the well-jointed Aymestry limestone, or other hard stratum, slid forward over the slippery Walker's earth, the character and composition of which seem to be similar to that analysed by Forbes.

The Wenlock Limestone.—The admirable description of this group by Sir Roderick Murchison leaves little to be supplied. Mr. Maw's estimate of 80 to 90 feet is probably not in conflict with Murchison's of 200 feet, as the latter includes the superior and inferior nodular strata, some of which will shortly be noticed. The limestone is earthy in aspect, and weathers to a prevailing dingy ashen or greenish yellow colour, but the remarkable green tint seen in the Dudley rock is not often to be observed here. When freshly broken, the limestone is hard, blue, or sub-

* Maw., *Geol. Mag.*, Dec. 2, vol. viii., 1881, p. 103.

crystalline; a very beautiful variety occurs near Easthope, where the crystalline crinoid stems and pink crystals of calcite stand out from the greenish, muddy, calcareous matter in which they are embedded. It is generally in thin beds, separated by shale bands, but where the limestone becomes thicker it is highly concretionary, and large lumps of pure crystalline limestone occur: These are called ball-stones. The railway cuttings and the old quarries along Wenlock and Benthall Edge display the limestones admirably, and the spoil heaps abound in fossils, which are not easily procured from unweathered limestone. The Limestone is, however, evidently largely made up of polyzoa, corals, and shells, round which the carbonate of lime has accumulated, and sometimes considerable thicknesses of it are made up of corals, such as *Heliolites*, *Favosites*, *Halysites*, *Acervularia*, still in their position of growth, but now partially crystalline with more or less loss of original structure. It is needless to quote a list of fossils from so well known a formation. The brachiopods are given in Dr. Davidson's paper already referred to; the others are to be found in "*Siluria*" and "*The Silurian System*"

Shales above the Limestone.—Mr. Maw prefers to include in the Wenlock Series a group of shales, about 100 feet thick, overlying the limestone, and related to it in their physical character, a view towards which Murchison also leaned. The abundance of *Rhynchonella Wilsoni*, Sow., links the shales with the Ludlow Beds, several forms are common to the shale and the Wenlock limestone, while the presence of *Strophomena furcillata*, McCoy, and the frequency of *Chonetes lepisma*, Sow., confer a certain individuality on the stratum.

One of the most striking bits of sylvan scenery in Shropshire is the valley excavated between the Wenlock limestone of Gleedon Hill and that of Tickwood, cut down deep into the underlying shales. This is known as Farley Dingle, and is the course taken by the railway from Buildwas to Much Wenlock. The road-cutting through the limestone of Wenlock Edge displays its general character admirably, as will be judged from the accompanying figure. (Pl. ix, B). Benthall Edge is the escarpment of the Limestone, which is divided from its continuation, Lincoln Hill, by the Severn Gorge, whose sides drop 470 feet in less than 350 yards. From this point the escarpment sweeps away to the south-west, and forms the ridge of Wenlock Edge, accompanied by the parallel Aymestry limestone ridge of Dinchope, Norton Camp, and Weo Edge.

The *Lower Ludlow Mudstones* and shales do not differ much from the underlying strata; they vary in colour from light to dark grey, but weather to an ashen grey. Immediately below the Aymestry Limestone come calcareous flags, which are often quarried. Between them and the Aymestry limestone seams of a soapy clay, called locally "Walker's earth," are often found, and are similar to those in the Wenlock shale. These clay seams are responsible for the land-slipping of the higher heavy masses of rock. The Lower Ludlow beds contain many fossils, *Chonetes lata*, Von Buch, *Rhynchonella nucula*, Sow., *Cardiola*, and other forms being of frequent occurrence.

The Upper or Ludlow Series.

The Aymestry Limestone.—An important development of limestone follows, and is named after its occurrence at Aymestry. It is characterised by the abundance of *Pentamerus Knightii*, *Homalonotus*, *Rhynchonella Wilsoni*, *Lingula Lewisii*, corals, and polyzoa. In places it is as much as fifty feet thick; but it varies very much, and is often split into several seams by intervening bands of shale, as is sometimes the case in the ridge parallel to Wenlock Edge about Shipton and Munslow. The limestone itself is blue to grey and sub-crystalline, of concretionary character, and in beds from one to five feet thick. It is brought up by a synclinal and anticlinal fold so as to underlie the Ludlow rock of Linley Brook.

The Upper Ludlow Rocks are very uniform in character, consisting chiefly of "thin-bedded, lightly-coloured, and very slightly micaceous sandstones, in some parts highly argillaceous, and in others so calcareous as to assume the character of impure limestones. They are greenish or bluish-grey in tint, weathering brown. A bone bed has been found in the Upper Ludlow rocks, about Bishop's Castle, by Mr. Garnett-Botfield, and by Mr. Randall at Linley Brook, where the upper series is remarkably thin, a fact to be alluded to later on.

The Upper Ludlow rocks are followed by a massive grey or yellow sandstone, the *Downton Sandstone*, much quarried for building, and of interest as yielding *Lingula cornea* in great numbers, together with the remains of *Pachytheca*, spherical bodies with radial structure, now generally referred to the Algæ. A second bone bed generally occurs at the junction of this rock with the Upper Ludlow; this is a gingerbread-coloured layer three or four inches thick, dwindling to a quarter of an inch in places, and made up of fragments of fish-bones, scales, and spines, with bits of *Pterygotus*, *Eurypterus*, conodonts,* and other organisms. This bed is visible about Ludlow, and has been found by Mr. Garnett-Botfield under the outliers of Downton Sandstone, capped by Old Red Sandstone, of Clun Forest, near Bishop's Castle. It was also discovered by the members of the Caradoc Field Club† at Diddlebury, but from that point, along Corvedale, has not been further recognised until Linley Brook is reached, where it was discovered and described by Mr. John

* J. Harley, *Quart. Journ. Geol. Soc.*, vol. xvii, 1861, p 542.
† *Caradoc Club. Record of Bare Facts*, 1891 [p. 11].

Randall, from the top of the Upper Ludlow rocks. It has not yet been made out under the small outlier of Downton Sandstone on the summit of the Long Mountain, although the rock here is characteristic and packed with specimens of *Lingula cornea*, Sow.

The *Tilestones* which come next in sequence are thin, sandy beds, separated by way-boards of shale. They are probably the equivalent of the yellowish-green micaceous flagstones, and green, red, and purple marls found on the same horizon in the Malvern district, and known as the Ledbury Shales.

The most characteristic feature in the scenery of Shropshire occurs in the Silurian Rocks, Wenlock Edge and its parallel ridges of Church Preen to the west, and Dinchope and Weo Edge to the east. It is noteworthy that the ridges due to the Wenlock and Aymestry Limestones are hardly ever of equal strength, if one rises the other drops, and the thickness of the two limestones tends to vary in inverse ratio. This bears out the concretionary character of the limestones in indicating that the calcareous matter has accreted to those portions of the series which were exceptionally rich in corals and shells. Moreover, the Aymestry limestone, at least, is not always upon one horizon (as originally suggested by Mr. Lightbody*), and often splits into two or three distinct divisions, separated by a considerable thickness of shales, while the great variation in thickness of the upper Ludlow, and the fact that at Linley Brook only about 50 ft. of strata intervene between the Aymestry limestone and the upper Ludlow bone-bed seems to require that the former should here be high up in the series.

Traced to the south-west and west, the parallel escarpments disappear, and the Wenlock and Ludlow strata become far less calcareous, until at the Long Mountain they contain very few shells, but are characterised by the presence of graptolites. The rocks are shales and mudstones, often with a concretionary fracture, and with occasional seams of limestone concretions. These are frequent about the horizon of the Aymestry limestone, above which the rocks pass into a series of coarse sandy flags. The following zones are recognisable by their graptolites† :—

4. Thin fissile shales, almost barren, but with *Cardiola* (U. Ludlow).

3. Hard thick flags, with occasional shales, *Monograptus Leintwardinensis*, Hopk., *M. Salweyi*, Hopk., *M. Roemeri*, Barr., (Aymestry).

2. Thin, muddy shales with rare flaggy ribs. *M. colonus*, Barr., *M. Nilssoni*, Barr., *Cardiola interrupta*, Broderip, (L. Ludlow).

* *Quart. Journ. Geol. Soc.*, vol. xix, 1863, p. 368.
† *Rep. Brit. Assoc.*, 1890, p. 817.

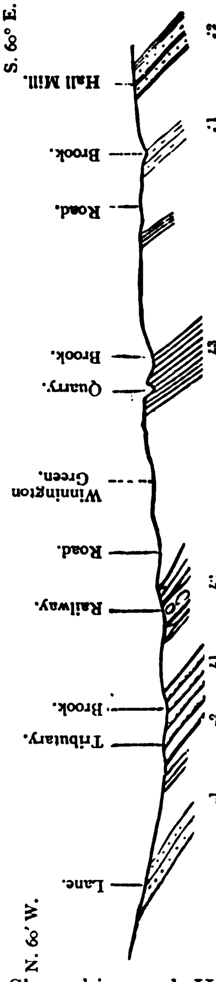

FIG. 14.—SECTION FROM MIDDLETOWN HILL TO PARTON WOOD.—*W. W. Watts.* (Scale, 3 inches to a mile.)

g^1. Pentamerus-beds. g^2. Purple Shales. h^1, h^2, h^3. Wenlock Beds. j^1, j^2. Ludlow Beds.

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1. Mudstones, earthy in the lower part, more calcareous above, *Cyrtograptus Linnarssoni*, Lapw., *M. Flemingii*, Salt., *M. dubius*, Suess, *M. serra* (Wenlock Limestone and Shale).

The general sequence of the lower of these beds will be seen from the accompanying section (Fig. 14).

Somewhat similar strata occur in the tract north of Clun Forest, and in the sequence there Mr. Garnett Botfield * has recognised a horizon of calcareous nodules which corresponds with the Aymestry Limestone in fauna and position. A curious faulted inlier of Silurian rock has been mapped by the Survey to the west of Caradoc, in which Mr. E. S. Cobbold † has detected fossils which enable him to split it up into the following divisions, Wenlock Limestone, Lower Ludlow, Aymestry Limestone, Upper Ludlow.

VII. OLD RED SANDSTONE AND NEWER ROCKS.

THE OLD RED SANDSTONE.

The Lower Member of the system which spreads out over Shropshire and Herefordshire is composed of alternations of "red and green argillaceous spotted marls, . . . alternating with sandstone" and "more frequently with irregular courses of concretionary impure limestone, mottled also with red and green." ‡ This is the well known Cornstone, a curious type of limestone containing no fossils, but characteristic of the Old Red Sandstone of Ireland and also Scotland, as well as of the

* *Caradoc Record of Bare Facts*, 1892, p. 23.

† *Caradoc Record of Bare Facts*, 1891 [p. 11].

‡ *Silurian System*, 1839, p. 175.

Permian and the Keuper. The Cornstone subdivision presents a series of escarpments overhanging the valley of Corvedale. Three principal groups of Cornstones will be found delineated on the Geological Survey Map. Flagstones also occur in this part of the county, some of those quarried having an area of 100 square feet.

The Upper Division of the Old Red Sandstone, the "Quartzose conglomerates and sandstone series" of Murchison, which is such a marked member of the series on the Fans of Brecon and the Black Mountains, is not very well displayed in Shropshire, but at the foot of the Clee Hills there are conglomerates and grits often so grey as to be mistaken for the Millstone Grit. The beds here appear to be conformable to the lowest carboniferous rocks, as they are inclined at the same angles and are affected by the same folds and dislocations; this conformity however is almost certainly deceptive as the Carboniferous limestone and Millstone Grit are locally absent or exceedingly thin, while on Shirlot Common, to the north, the Coal measures crop out within a distance of a quarter of a mile from the Upper Silurian boundary.

The Carboniferous System.

Space forbids any detailed account of these rocks, a matter of little consequence, as not many opportunities will be afforded to the Association of seeing any of them. They are, however, of interest to the physical geologist, from the mere fact that they form part of one of the Midland Coalfields, in all of which the relations of the lower beds are peculiar. *The Carboniferous Limestone* is present only at Lilleshall and the Wrekin to the north and at the Titterstone Clee Hill to the south. *The Millstone Grit* is present at both these places, and extends further south from the Wrekin and further north from the Clee than the Limestone. In the central region of the Forest of Wyre, Shirlot, and the Shrewsbury coalfield the *Coal Measures* rest directly on older rocks. Both Limestone and Millstone Grit are thin and impure and not at all of the nature and importance that they attain in the North Shropshire and South Welsh Coalfields. The productive measures are divided into four distinct fields, those of Shrewsbury, Coalbrookdale, the Clee Hills and the Forest of Wyre. A full account of the rocks will be found in Murchison's "*Silurian System*"; in Professor Prestwich's paper in *The Transactions of the Geological Society*, vol. v; in Professor Hull's "*Coalfields of Great Britain*"; in Mr. John Randall's communications to *The Mining Journal*, and his more recent papers, and in the papers of Mr. D. Jones; while a paper full of research showing that the Upper Coal Measures rest in a great hollow denuded in the Lower Measures, the Symon Fault as it was called, by Mr. M. W. T. Scott, will be found in *Quarterly Journal of the Geological Society*, vol.

xvii, 1861, p. 457. It may be noted that the head of a Labyrinthodont, *Loxomma*, has been found in the Coal Measures at Madeley.

THE PERMIAN SYSTEM.

Mr. D. C. Davies * considers that the rocks of this system are conformable to the Carboniferous along the northern margin of the Shrewsbury coalfield, although at Ifton to the north they are unconformable, and although such conformity is not consistent with the facts to be immediately mentioned. The rocks about Alberbury are 700 to 800 feet thick, and consist of red and purple sandstones and marls, without fossils, at the base, followed by a remarkable calcareous breccia, 400 feet thick, made of fragments of carboniferous limestone and of the *Spirorbis* limestone of the Shrewsbury coal measures. Many of these fragments are very large and angular, and they are associated with rounded fragments of quartz, chert, and slate, all set in a reddish, sandy, calcareous matrix. Traced farther to the east, this bed appears to pass into calcareous conglomerate, of which there are two seams in the sandstones of Enville covered by the "trappoid breccia," which is such a remarkable feature of the Permian there and in the Abberley and Clent Hills. Professor Hull † places these rocks in the lower division of the Permian system. A few ill-preserved plants occur in them.

THE TRIAS.

The Triassic Rocks of Shropshire call for no particular remark, except that at Grinshill they have yielded bones and tracks of *Rhynchosaurus*. They fall into the usual divisio ns,and are covered about Wem by Rhætic rocks.

THE RHÆTIC ROCKS.

The *Rhætic Rocks* are described by Mr. G. Maw ‡ at Audlem as containing the usual fossils, *Avicula contorta*, Portl., *Pullastra arenicola*, Strick., *Cardium Rhæticum*, etc.

These are followed by the clays, shales, and limestones of Wem,§ which belong to the lowest division of the Lias and are covered by a small outlier of Marlstone. The zones represented are from that of *Ammonites planorbis*, Sow., to that of *A. Jamesoni*, Sow., or *A. Henleyi*, Sow. Above the Lias occurs a great gap in Shropshire geology, and the next deposits belong to the Pleistocene period.

* *Quart. Journ. Geol. Soc.*, vol. xli, 1885; *Proc.*, p. 107.
† *Mem. Geol. Survey*. The Triassic and Permian Rocks, 1869, pp. 13 and 21.
‡ *Geol. Mag.*, vol. vii, 1870, p 203.
§ H. B. Woodward, *Mem. Geol. Survey of Gt. Britain*. The Jurassic Rocks.

THE PLEISTOCENE DEPOSITS.

Boulder Clay occurs in several parts of the county, and it is in connection with it that the Boulders found scattered so widely are undoubtedly associated. These belong to two broad groups, as shown in the maps of Mr. D. Mackintosh,* and Mr. Martin,† those of granite from Criffel, and those of lavas, ashes, and granites from the English Lakes, including Eskdale. These Boulders are strewn in immense numbers, and often of large size, from Stafford to Wolverhampton, Wellington, and Much Wenlock, and may be especially well seen about Bridgnorth, and Eaton Constantine, where almost every wall is built of them. In addition, however, a few boulders of Welsh felsites and andesites, chiefly from the Arenig district, are to be found in the rear of the greater mass of those met with about Harborne and Frankley Hill. Mr. Martin supposes that these are the relics of an earlier dispersal, masked later by the distribution of Scottish and North British erratics.

The so-called *Mid Glacial Sands and Gravels* are well represented in Shropshire, and have been described, with a list of their marine shells, by Mr. A. C. Nicholson,‡ from Gloppa, near Oswestry. The sands here occur between 900 and 1,160 feet above the sea, marine shells having been found up to 1,120 feet. The gravels contain many far-travelled and striated stones, some of which come from Scotland, and others from the English Lakes.

A very interesting deposit, probably of the same date, is described by Mr. G. Maw,§ from the Severn Valley, between Shrewsbury and Bridgnorth. It is exposed at Buildwas and Strethill, and its character can be judged from the accompanying section (fig. 15), which Mr. Maw has kindly allowed us to print.

At Buildwas nothing but clean, falsebedded sands and gravels are to be seen, but at Strethill while the lower and upper strata are of this character, the middle bed, 60 feet thick, is "a most heterogeneous mass of drift, in which stratification is almost absent." "The middle of this heterogeneous stratum consists of a mass of very tough unstratified clay, containing fragments of Wenlock shale, waterworn and sub-angular boulders, pieces of flint, and patches of curiously contorted sand and silt." A list of 41 fossils, mostly marine shells, is given by Mr. Maw, and another, of the rocks found as fragments throughout the deposit, including syenite, Cumberland and perhaps Scottish granites, Cambrian rocks, flints, all of which are likely to be far-travelled, with others of more local derivation. It only remains to be added that the top of this deposit is 300 feet above the sea, and that

* *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, p. 425.
† *Birm. Phil. Soc.*, vol. vii, 1890, p. 1.
‡ *Quart. Journ. Geol Soc.*, vol. xlviii, 1892, p. 86.
§ *Quart. Journ. Geol. Soc.*, vol. xx, 1864, p. 130.

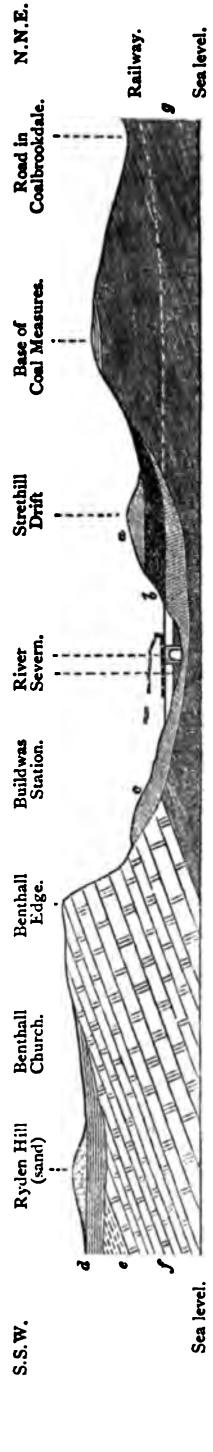

FIG. 15.—SECTION ACROSS THE VALLEY OF THE SEVERN AT THE NEW BUILDWAS RAILWAY BRIDGE.—*G. Maw.*

a. Sand and Gravel. *b.* Gravelly Clay. *c.* Sand and Gravel. *d.* Base of Coal Measures. *e.* Ludlow Rock. *f.* Wenlock Limestone. *g.* Wenlock Shale.

Vertical Scale, twice the Horizontal.

The gravel beds represented on the left-hand side of the valley occur a little to the north of the actual line of section.

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correlated gravels occur at many places in the neighbourhood, and reach a height of 800 feet at Burton, near Much Wenlock. The physical appearance of the gravel-ridges about Buildwas reminds one of Eskers, but Mr. Maw points out that at Strethill the stratification bears no relation to the present outline of the mounds. Similar mounds occur between here and Shrewsbury, often enclosing the relics of old lakes (now peat deposits) between them. Indeed, from the end of the Glacial period, up probably to the beginning of history, there was an epoch of lakes in Shropshire; several of them are mentioned by Miss Eyton,* the chief being that of the Weald Moors, seven miles long and four miles broad. The lowest deposit reached in this by deep draining is sand, followed by blue clay, and that by six feet of peat.

VIII. THE IGNEOUS ROCKS OF SHROPSHIRE.

On account of the absence of evidence it is not always possible to ascertain the exact geological age of the intrusive igneous rocks of this county, and it is not at all improbable that some of the rocks intrusive into the oldest groups may be of comparatively recent date.

* *Notes on the Geology of North Shropshire.* London, 1867, p. 78.

Post-Longmyndian Dolerites.

We are indebted to Mr. G. Wilson for the loan of two specimens and slides from the rocks intrusive into the Longmyndian sediments, one from Ratlinghope and one from Wentnor. Both are dolerites, the first being coarse grained and ophitic with plagioclase, augite, iron ores and abundant hypersthene, the felspar having crystallised first, and being embedded in hypersthene and augite. Olivine is absent, and the rock is singularly like a coarse dolerite collected by the same gentleman from Little Caradoc, while some of the coarser-grained Shelve dolerites, and especially those of the Breidden chain, also resemble it. Probably the rocks are connected with the post-Silurian intrusions of these areas.

The Wentnor specimen is of a different type, granular felspar and chlorite (after augite or hypersthene) being embedded in a fine-grained matrix. This type is somewhat, but not exactly, like the Llanfawr-dolerite set of intrusions to be mentioned a little later on.

Rocks in the Uriconian Areas.

These have been described by Mr. Allport,* Professor Bonney, † and Mr. Rutley. ‡ In the early edition of the Geological Survey Map an attempt, and a moderately successful one, was made to separate the "felspathic traps" from the "greenstones," but in the second edition a single tint was made to do duty for both.

Mr. Allport demonstrated that the Wrekin "greenstone" and that of the Lea Rock were partly made of flows of felsitic lava containing porphyritic crystals of orthoclase and plagioclase felspar embedded in matrices in which minute microlites indicate the flow structure. In some varieties of the rock there are isolated spherulites, but more usually these run together into bands (the axiolitic structure of Zirkel). Perlitic cracks are also present in singular perfection, even when the glassy base of the rock has undergone devitrification. From these characters Mr. Allport determined that the rock had been originally a glassy pitchstone. He also noticed the ashes made up of fragments of these rocks, and the intrusive dykes of altered olivine-basalt by which the older lavas were penetrated.

Professor Bonney gives a further account of these Wrekin rhyolites from the main chain and from Burcot in the Wrockwardine mass. He also describes the grey or greenish rhyolite of the Ercal quarry, which is of the same type as the Wrekin lavas, and concludes that it is a dyke in the granitoid rock of that locality. The latter contains quartz, orthoclase, plagioclase, with microcline, and a small quantity of chlorite; indications of a minute graphic structure are at times present.

* *Quart. Journ. Geol. Soc.*, vol. xxxiii, 1877, p. 449.
† *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, p. 662; *Ibid.*, vol. xxxviii, 1882, p. 124.
‡ *Quart. Journ. Geol. Soc.*, vol. xlvii, 1891, p. 534.

The Gneiss of Primrose Hill is occasionally well foliated and contains quartz, felspar, mica, chlorite, and probably epidote. Diorite is also quoted as a part of the Primrose Hill complex.

From Caradoc, Professor Bonney examined a clastic rock made of fragments derived from rhyolitic and granitoid rocks. Mr. Rutley gives a description of rhyolitic lavas and ashes of Wrekin type from Caradoc and also records melaphyre-tuffs and melaphyres from the same hill. The latter are mainly made up of a matrix, now devitrified, of a pale brown tint, embedding skeleton crystals of labradorite and also lath-shaped crystals of triclinic felspar. The rock is often amygdaloidal, and fragments and bombs of it occur in the tuff. He takes these rocks to be altered andesites or basalts. Professor Bonney describes a spherulitic rhyolite and a rhyolitic agglomerate from Lilleshall.

The Western Uriconian range of Callaway shows spherulitic rhyolites at Pontesford Hill and at a few other points, together with rocks which have been described as hornstones and hälleflintas; several basic rocks occur, including the doleritic rocks of Pontesford and the coarse-grained diorite of Knolls Ridge.*

POST-CAMBRIAN ROCKS.

There is only one known dyke in the Cambrian rocks of Salop. It appears to be intentionally indicated in Prestwich's † map, but was afterwards merged with the post-carboniferous dolerites, and does not appear to have been since noticed. It is exposed along the road-cutting from the Hatch to the Wrekin, and is macroscopically a red rock with greenish patches. It is intrusive in the Shineton Shale which it hardens and alters considerably, but it does not alter the Carboniferous rocks. Microscopically it is very much like the diorites described by Mr. Allport ‡ from the Cambrian shales of Nuneaton; especially those from Griff Farm and Marston Jabet. The felspar is red and a good deal decomposed, and is set in hornblende, which rarely shows crystalline outlines and is much altered into chlorite; apatite is generally present. The variety of Maddox Hill would be more accurately described as a porphyrite with porphyritic crystals of felspar set in a complex of minute felspar needles and hornblende crystals; it also corresponds with a fine grained variety described by Mr. Allport ‡ from Marston Jabet.

Rocks somewhat similar to this type are found associated with ancient sediments in many localities; Brazil Wood in Leicestershire, Anglesey, the Lleyn Peninsula, the English Lakes; and even in the Highlands of Scotland, about Inchnadamff and Loch Assynt.

* La Touche, *Caradoc Bare Facts*, 1893, p. 19.
† *Trans. Geol. Soc.*, Ser. 2, vol. v, 1840, p. 413.
‡ *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, p. 637.

FIG. 16.—VIEW OF THE ROUNDTAIN (ARENIG LAVA) LOOKING NORTH.
(From a Photograph by the REV. D. J. MACLEOD, *of Hope.)*

IGNEOUS ROCKS ASSOCIATED WITH THE ORDOVICIAN OF SHELVE.

These fall naturally into two great groups—the *interbedded* andesitic ashes and lavas of Arenig and Bala ages, and the *intrusive* dolerites and picrites. The ashes contain some bands of breccia, in which fragments of volcanic glass, of rhyolite, and andesite are the chief constituents, embedded in a matrix of broken crystals of felspar, etc. Often, however, the tuffs are finer grained, and are made up chiefly of comminuted crystals with a few rock fragments. There are ashes upon three chief horizons, but smaller intermediate bands are not infrequent throughout the whole series, except that they are rather less frequent in the Llandeilo Series than elsewhere. The chief lavas discovered in the Shelve district are those of Arenig age in the Stapeley Hills from Llanfawr to Symonds Castle, attaining their greatest thickness and extent on Todleth. Figure 16 is a view of the escarpment of the lavas at the Roundtain as seen from the south, from a photograph taken, and kindly presented to us, by the Rev. D. J. MacLeod. Figure 17 is from a photograph of the columnar andesite on the east crags of Todleth. The rocks are andesites containing porphyritic crystals of plagioclase felspar, augite, and hypersthene—or not infrequently both of the last two minerals—

FIG. 17.—VIEW OF COLUMNAR ANDESITE ON THE EASTERN CRAGS OF TODLETH.

in a fine microlithic matrix. Often the phenocrysts are aggregated into groups, and in some of the lavas of Llanfawr these groups are large enough to be easily seen with the naked eye. Both hornblende and olivine are absent from these rocks, and indeed from all types but one in the district. The structure of these rocks will be judged from figure 18. A well-marked set of lavas belonging to a more recent horizon than those of Todleth occur in the Breidden Hills, about the horizon of the Hagley volcanic rocks of the Shelve district; they are like the Arenig lavas, but contain rather more and better preserved hypersthene, as is shown in the annexed figure (Fig. 19).

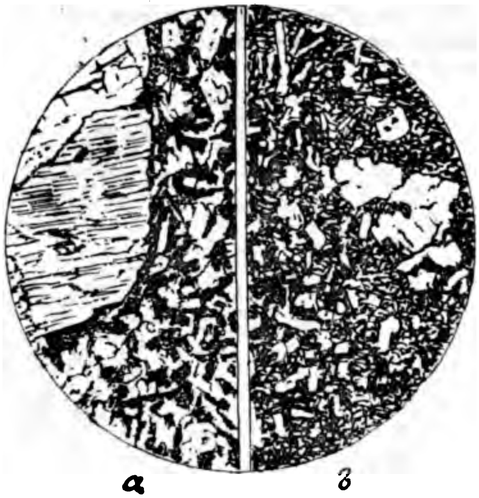

FIG. 18.
a. ANDESITE WITH PORPHYRITIC AUGITE; Llanfawr, x 25.
b. ANDESITE WITH PORPHYRITIC FELSPARS; Roundtain, x 12.

FIG. 19.—ANDESITE WITH PORPHYRITIC HYPERSTHENE AND FELSPAR; Moel-y-Golfa, Breiddens, x. 25.

The Ordovician rocks of the Shelve area are pierced by a vast number of intrusive dykes and sills, chiefly of hypersthene dolerite, a very typical ophitic rock consisting of hypersthene, augite, plagioclase (labradorite), and iron ores. The date of these intrusions can be fixed with fair accuracy as they come into contact with and somewhat alter the *Pentamerus* limestones, and are therefore of post-Llandovery age. The annexed figure (Fig. 20) is taken from a slide of the ophitic dolerite.

FIG. 20.—OPHITIC DOLERITE; Shelve Church; taken with crossed nicols, x. 25. Felspar ophitically set in augite.

A peculiar type of fine-grained dolerite occurs on Llanfawr. It is not ophitic, and contains a large quantity of hypersthene. It is intrusive in the andesites of that locality, and appears to be more basic than the rest of the dolerites.

FIG. 21.—PICRITE; Erratic, from near Hyssington; taken with crossed nicols, x. 25. Olivine set ophitically in augite.

The picrites of the Shelve area, etc., are very interesting rocks. They occur mainly in the great boss of Cwm-mawr, and their fragments are spread out over the land as groups and lines of boulders. They consist of granules of olivine embedded ophitically in great plates of augite. A little brown mica is usually present and very little interstitial felspar, while the olivine is often converted into serpentine and also into pilitic hornblende. The plates of augite and embedded olivine grains may be seen in the annexed figure (Fig. 21).

THE INTRUSIVE SILLS AND LACCOLITES.

The authors have paid special attention to the relationship between the igneous and sedimentary rocks in the Shelve area with the result of ascertaining how intimately the structural dis position of the latter fixes the position and shape of the former. The igneous rocks come up more or less vertically along faults, sharp bends, twist- and strain-lines; and more or less horizontally into the spaces formed by the differential movement of the superposed rock-sheets during folding. Of the first, the dyke cutting off the ashes at Round Hill may be taken as an example; of the second, the dykes at the east of Todleth, the Roundtain, and Bromlow Callow; of the third, the set of dykes running across the north-east of the district from Lower Wood to Hedsall and Grimmer, which are not in continuous lines but in separate short dykes grouped *en échelon*. The fourth type demands somewhat fuller attention, as it was the first case in which the so-called *laccolitic* or *lens-sill* structure was definitely ascertained and placed on record in Britain.* The great central igneous mass of the district, Corndon, is a *laccolite* or intrusive cake-like mass of igneous material, and it fortunately shows sections which display its structure most unequivocally, as both the top and the bottom of the lens-sill are to be seen. The south and west slopes of the hill incline at a low angle, and the Corndon dolerite dives gently down under shales, which are altered into the rock known as spilosite for a considerable horizontal distance from the junction line. The east and south-east sides, however, are precipitous, and the dolerite breaks away into a series of crags, giving rise to screes, where denudation goes on rapidly, and in such a way as to make it clear that there is some soft shaly rock underlying the dolerite, and allowing it to be undercut by rain and springs. At one point on this side a small quarry has been opened, which proves that the structure is that which was inferred from the undercut crags, for the main mass of the dolerite at that locality is seen to rest conformably on the bedding-planes of the altered shales beneath it.

* Watts, *Rep. Brit. Assoc.*, 1886, p. 670.

The structure of the hill, therefore, is not the pyramidal boss which is usually figured in sections and books,* but a lens-like cake or cakes—in other words, a *laccolite*—corresponding to those described by Gilbert† in the Henry Mountains. It wedges more or less conformably between the strata, rests on an almost flat sole of bedded rock, lifts the more sharply curved strata above it on its back, and thins out to a feather edge all round. This is illustrated by the section given below (Fig. 22), which shows also the undercut (east) and overcut (west) side of the Corndon Laccolite, which is, however, not so much a simple laccolite as a laccolitic group. This great igneous injection occurs in the main anticline of the country, and was dammed down by the comparatively rigid cover of Arenig ashes above it. It is almost certain that the differential bending movement of this ash band above and the Hope shale below during the folding of the rocks determined the position of the laccolite at this point. The ash bed arched as a whole, the shale crumpled irregularly, and the tensional area, or space opened, between the two was the place taken advantage of for the intrusion of the dolerite magma.

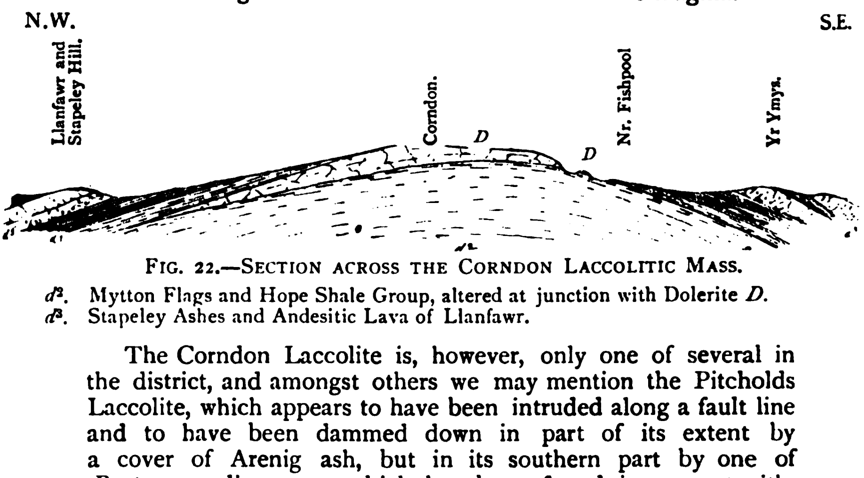

FIG. 22.—SECTION ACROSS THE CORNDON LACCOLITIC MASS.

d^2. Mytton Flags and Hope Shale Group, altered at junction with Dolerite *D*.
d^3. Stapeley Ashes and Andesitic Lava of Llanfawr.

The Corndon Laccolite is, however, only one of several in the district, and amongst others we may mention the Pitcholds Laccolite, which appears to have been intruded along a fault line and to have been dammed down in part of its extent by a cover of Arenig ash, but in its southern part by one of *Pentamerus* limestone, which has been found in contact with, and altered by, the intrusive mass at its southern margin. Although no actual junction has hitherto been discovered, there can be little doubt that a similar story is told by the Wilmington sheet to the north, which appears to have been fed by more or less vertical dykes, to rest on the *eroded edges* of the Ordovician rocks below, and to have been kept down by a cover of Silurian rocks.‡

* *Geol. Survey*, *Horizontal Sections*, Sheet 33.
† *Geology of the Henry Mountains.*
‡ *Rep. Brit. Assoc.*, 1886, p. 670.

Further, there is every transition here between the laccolites, or lens-sills, and ordinary sills or intrusive sheets, the limiting conditions having generally been the breadth and consequent weakness of the covering arch of rock. Thus, where the central anticline is moderately broad the single laccolite is dented or *sags* in the middle (the outline of Corndon shows this), but where it becomes much broader there is no single laccolitic mass, but a couple of corresponding sills on the opposite limbs of the anticline.

One further point to be noticed is that the laccolites usually show a rude stratification, as though they had been filled in gradually, each successive uplift having been accompanied by a new injection of doleritic magma, and occasionally even small *shells* of shale are included between and conformably to the successive injections; indeed, the shells are sometimes even isolated.

Post-Carboniferous Intrusive Rocks.

These have been so excellently described by Mr. Allport* that there is little to add. They are dolerites or basalts, in which the felspar is idiomorphic, with brownish augite, generally granular, but often showing traces of crystal outlines. Iron ores are abundant, and large porphyritic grains or crystals of olivine, more or less converted into serpentine, or serpentine with calcite. A zeolite is sometimes present between the felspar crystals, which may possibly be analcime.

These basalts and dolerites occur on the Clee Hills as intrusive sheets in the Coal Measures, and at Kinlet on a similar horizon; nearer the Wrekin they are on a lower horizon, and are generally in contact with the Millstone Grit; while quite near the Wrekin they form the floor on which the Carboniferous limestone rests.

IX. HISTORICAL SUMMARY.

It will simplify matters if the reader will bear in mind the broad fact that the county of Shropshire is divisible, both geographically and geologically, into two regions,—namely the region of the Shropshire Plain to the north (floored by strata mainly of post-Carboniferous age), and the region of the Shropshire Uplands to the south (floored by strata mainly of pre-Carboniferous age); and that the strata to be noticed and visited upon the present occasion are those of the Upland region alone.

In this upland region we have a central or basal core of Barren strata, namely those of the district of the Longmynd, originally termed "Cambrian" by Murchison and his successors.

This core of Barren rocks is flanked on both sides by an overlying fossiliferous series—the original "Silurian" of Murchison

* *Quart. Journ. Geol. Soc.*, vol. xxx, 1874, p. 529.

and his successors, and this series is followed in turn, first by the strata of the Old Red Sandstone, and next by those of the Carboniferous.

In glancing at the history of discovery among these ancient strata of the Shropshire Uplands, it will be most convenient if we follow the footsteps of the discoverers themselves, and proceed downwards from the summit of the Carboniferous to the central and axial strata of the district of the Longmynd.

CARBONIFEROUS.

It is to Mr. A. Aikin * that we owe some of the earliest descriptions of the Carboniferous Rocks of Shropshire; although Murchison † had previously defined clearly the differences between the Carboniferous and the Silurian Limestones. Mr. Aikin's material was subsequently placed at the disposal of Professor Prestwich,‡ who made such good use of it, and added to it the results of such a series of important researches, that his memoir on the Carboniferous strata of Shropshire is not only a classic in British Geology but in all its main features it still remains the best account of the local strata that we possess.

OLD RED SANDSTONE.

To the joint labours of Sedgwick and Murchison we are not only indebted for the elevation of the Old Red Sandstone to the rank of a system, but from the pen of the latter we have, in his *Silurian System*, and in his *Siluria*, an account of the Old Red Sandstone which has hardly been improved upon by subsequent research. Indeed so little has been worked out in detail among this very uninviting series of rocks, that we have, up to the present time, hardly any knowledge of its component divisions. We do not know accurately the relations of the Shropshire Old Red Sandstone to the Carboniferous above, nor are the actual relations of its lowest and more fossiliferous members to the Silurian below as yet clearly and definitely settled.

It is true that the generally barren nature and the monotonous lithological characters of the strata composing the main mass of this Old Red System hardly recommend it at first sight as a promising field of research. Yet, if some of the local zones could be clearly recognised and mapped out, we might learn much more about the conditions under which the Old Red rocks of the county were originally formed, and be enabled to fix the true relationship of the Shropshire type of this system as a whole as regards date and mode of origin to the acknowledged and typical Devonian rocks of Devonshire and the continent of Europe.

* *Trans. Geol. Soc.*, vol. i, 1811, p. 191.

† *Silurian System*, 1839, p. 99.

‡ *Trans. Geol. Soc.*, Ser. 2, vol. v, 1840, p. 413.

THE "CAMBRIAN" AND "SILURIAN SYSTEMS" OF MURCHISON.

Below the Old Red Sandstone of Shropshire comes that enormous series of Lower Palæozoic and pre-Palæozoic strata first described as a whole by Murchison in the classical pages of the *Silurian System*. He pointed out that this enormous series was constituted of two grand members—namely a basal and Barren series of the Longmynd area below (which he correlated with Sedgwick's "Cambrian") and an overlying and Fossiliferous series above (which he erected into his original "Silurian System"). This Silurian System as thus defined was divided by him into two parts—an "Upper Silurian" shading up into the Old Red Sandstone above, and a "Lower Silurian" shading down into the basal "Cambrian" (Longmynd) below. The theoretical line of division between his Upper and Lower Silurian ran vaguely across the low ground of Central Shropshire from the neighbourhood of the Craven Arms to Wellington, and along this line the rocks and faunas of the Lower and Upper Silurian were supposed to graduate the one into the other. As most geologists are aware, the progress of discovery soon led Murchison to recognise the fact of a general unconformity, in Shropshire, between his "Lower" and "Upper Silurian," and the work of the Geological Surveyors demonstrated the fact of a corresponding palæontological break. This break, however, was supposed to be bridged elsewhere by a transitional formation, the Llandovery, which was assigned in part by Murchison to his "Lower," and in part to his "Upper," "Silurian." At present, however, this Llandovery formation is by general consent united wholly to the latter. This plan was first proposed by Sir Charles Lyell, and the system thus constituted by the Llandovery, Wenlock, and Ludlow formations is the typical Upper Silurian of the text-books of Lyell, Dana, and Sir Archibald Geikie. The limits of Murchison's three great systems, as figured on the maps of the Geological Survey, are shown in the map (Fig. 23), which is on the same scale as that in Fig. 1.

Again Barrande's magnificent results in Bohemia placed it beyond question that the strata of the "Système Silurien" of that country embedded three successive and distinct faunas, of which the third and most recent only is that of Lyell's Upper Silurian, the first and second faunas being both met with in the strata lying between this Upper Silurian and the Barren or axial series at the base. In other words the "Silurian" era is not bi-partite but tri-partite in character. This is now acknowledged to be universally the case wherever the Lower Palæozoic fossiliferous series has been fully investigated outside the Shropshire area. How the recent discoveries made in Shropshire have led to precisely the same conclusion will be seen in the sequel—Murchison's

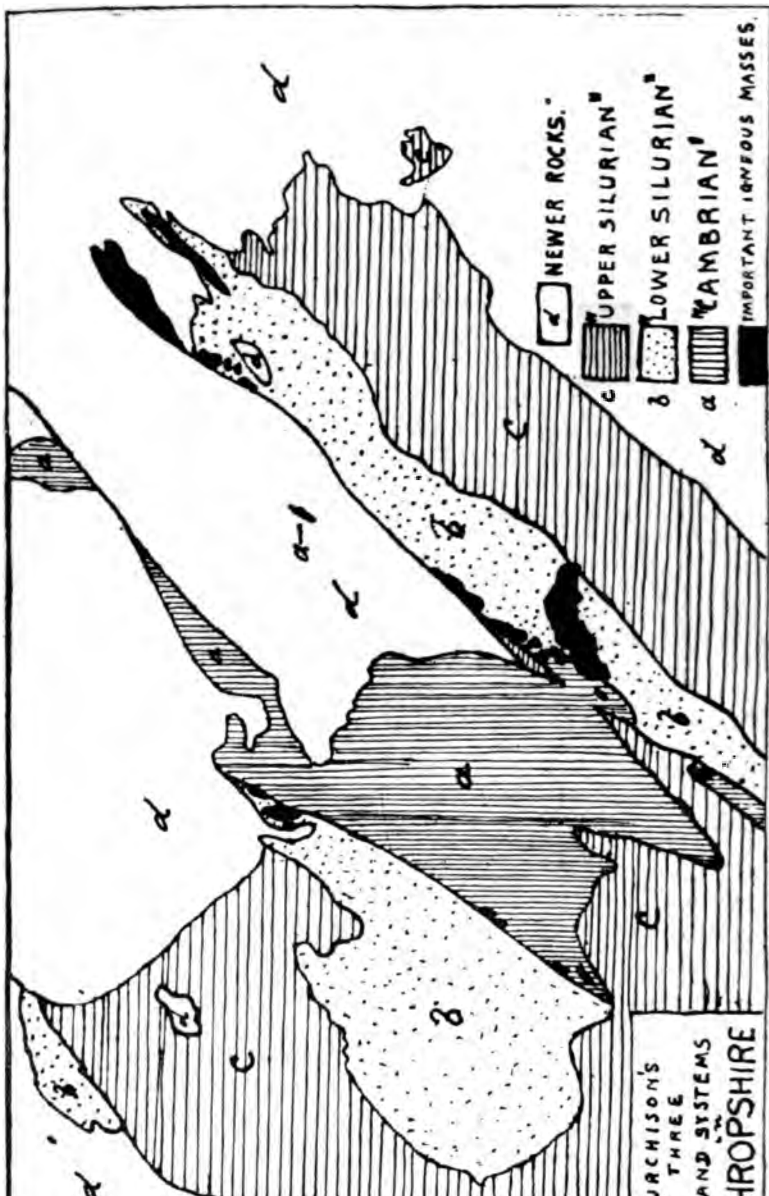

FIG. 23.—MAP OF PART OF SHROPSHIRE TO SHOW MURCHISON'S THREE SYSTEMS.

original "Silurian" having been recently shown to embrace strata not only of the second but of the first fauna.

Thus the great series of Fossiliferous rocks which lie between the Old Red Sandstone above and the axial or Barren series below is now known to constitute everywhere three natural sub-equal systematic divisions or systems, each division having its own special and peculiar fauna—namely the *first*, *second*, and *third faunas* of Barrande, respectively.

We may therefore either group these three great divisions as the three component members of one grand system—the *Silurian*, or we may regard them as the three component systems of the Lower Palæozoic or *Protozoic* cycle, and employ the term Silurian for the highest of the three, as being that system which was first and most fully worked out by Murchison himself.

The first of these plans is that which is followed by the younger French geologists; who term the whole Lower Palæozoic cycle *Siluric*, and name its three component systems "Cambrien," "Ordovicien," and "Silurien" (or "Gothlandien").

The second is the plan followed by the younger British Geologists; who divide the Lower Palæozoic cycle or *Protozoic* into the three systems of the "Cambrian," "Ordovician," and "Silurian" (or "Salopian").

It is idle to enter here upon the history of the wearisome controversy as to the proper use of the names Cambrian and Silurian, or to point out how natural it was for the followers of Sedgwick to term the first and second of these systems *Lower* and *Upper Cambrian*; and for the followers of Murchison to term the second and third *Lower* and *Upper Silurian*.

The facts remain the same whatever may be the nomenclature adopted: and the work and fame of Murchison and Sedgwick remain unaltered so long as no violence is done to the facts of nature.

We give the following table for the convenience of those who desire to compare the various nomenclatures employed by the geologists who have referred to the Shropshire sequence.

Discoveries among the Strata connected with the original "Upper Silurian" of Murchison.

The *Salopian* or Silurian proper of the present day (which is identical with the Upper Silurian of Lyell) includes not only the whole of the original Upper Silurian of Murchison, but embraces in addition the Llandovery rocks, now universally recognised as the basal formation of the rocks of the third fauna.

This Silurian series, as thus defined, is most magnificently developed in Shropshire, and constitutes the Shropshire or Salopian system par excellence. It sweeps in one practically

THE LOWER PALÆOZOIC ROCKS OF SHROPSHIRE.

Table explanatory of the nomenclature employed in Memoirs published between 1839 and 1894.

Systems.	Series.	Groups.	Lapworth, Callaway, Hicks, Nicholson, &c., 1879-1894.	Barrois, Bigot, de Lapparent, &c., 1889-1894.	Geikie, 1893-4.	Lyell, 1871-84.	Barrande, 1852-87.	Sedgwick, 1830-60.	Maps and Memoirs, Geological Survey, 1840-1893.	Murchison *Siluria.* 1857.	Murchison *Silurian System,* 1839.
Old Red Sandstone of Shropshire and Herefordshire.											
UPPER SYSTEM. 3rd Fauna of Barrande (in part). (*Silurian or Salopian.*)	Upper or Ludlow Series.	Passage Beds and Downton Sandstone. Upper Ludlow Shales and Flags. Aymestry and Ludlow Limestone.	Silurian System (Sedgwick).	Silurien Supérieur Gothlandien or Silurien.	Upper Silurian.	Upper Silurian.	Faune Troisième.	Silurian.	Upper Silurian.	Upper Silurian.	Upper Silurian.
	Middle or Wenlock Series.	Lower Ludlow Shales. Wenlock Limestone. Wenlock Shales. (Woolhope Limestone.*)									
	Lower or Llandovery Series.	Tarannon Purple Shales. Upper Llandovery and *Pentamerus* Limestone. (Lower Llandovery.*)									Lower Silurian.
MIDDLE SYSTEM. 2nd Fauna of Barrande. (*Ordovician.*)	Upper or Bala Series.	Trinucleus and Acton Beds. Longville Flags. Chatwall Sandstone. Harnage Shales. Hoar Edge Grits.	Ordovician System (Lapworth).	Silurien Moyen or Ordovicien.	Lower Silurian.	Lower Silurian.	Faune Seconde.	Upper Cambrian.	Lower Silurian.	Lower Silurian.	
	Middle or Llandeilo Series.	Rorrington Black Shales. Meadowtown Limestone and Flags. Weston Beds.									
	Lower or Arenig Series.	Stapeley Ashes. Hope Shales. Mytton Flags. Stiper Stones Quartzite.									
LOWER SYSTEM. 1st Fauna Barrande. (*Cambrian.*)	Upper or Olenidian Series.	Shineton Shales.	Cambrian System (Lyell).	Silurien Inférieur or Cambrien.	Cambrian.	Cambrian.	Faune Primordiale.	Middle Cambrian.			
	Middle or Paradoxidian Series.	Comley or Hollybush Sandstone. Upper part with *Paradoxides.*									
	Lower or Olenellidian Series.	Lower part of Comley Sandstone with *Olenellus.* Wrekin Quartzite.									

Non-fossiliferous Basement Rocks, Longmyndian and Uriconian (Callaway), Lower Cambrian and Monian (Blake), Cambrian (Murchison and the Geological Survey).

* These groups, unrepresented in Central Shropshire, are given from [illegible]

unbroken mass north and south from Wellington to Ludlow, westwards across the country to Montgomery, and thence north-east from Chirbury to the Valley of the Severn near Westbury, thus completing three-fourths of the entire circle of the Shropshire Uplands. The most striking features of Shropshire scenery—the long sweep of Wenlock Edge, the heights of Bishop's Castle and the broad swell of the Long Mountain—are all composed of the rocks of this system, which is as characteristic of Salop as the Devonian is of Devonshire.

The title "Salopian," which was originally proposed for the Wenlock Edge and Lower Ludlow series (the central and typical member of the system), thus becomes a very natural and convenient alternative name for the British strata of the third fauna.*

On comparing the first with the second edition of the Geological Survey Map of the district it will be found that the base of Murchison's Upper Silurian on the former is merely a rough provisional line, which crosses and recrosses the line drawn in later years to define the exact and true unconformable base of the May Hill or Llandovery Sandstone.

Reference to the memoirs of Phillips,† Sedgwick and McCoy,‡ Salter and Aveline,§ and others between the years 1850 and 1856, will give the history of this question and of the gradual determination of the invariable unconformity at the base of the Silurian System in Shropshire. This unconformity, although it actually exists everywhere along this line from near the Craven Arms to Shineton and the Wrekin, dividing the Bala Series and its fauna from those of May Hill or Llandovery, is one that was very naturally mistaken for conformity by Murchison and his successors, owing to paucity of sections and the nature of the ground; and although an unconformity had been early discovered and correctly mapped in the western part of Central Shropshire, that to the east was only demonstrated finally by the accurate mapping of Messrs. Aveline and Salter for the Geological Survey.|| Add to this the fact that along this line the non-recognition of the existing unconformity led to the almost inevitable commingling of ¶ Bala, Llandovery, and Wenlock fossils in the collections; and the original belief of Murchison and his immediate successors that the so-called Lower and Upper Silurian types of life were commingled in Shropshire, is very naturally accounted for.

Phillips,† Sedgwick, and McCoy,‡ however, working in other districts, were the first to recognise that the May Hill or Llandovery fauna of the Silurian was quite separate and distinct

* Cf. Lapworth, *Geol. Mag.*, Dec. 3, vol. viii, 1891, p. 539.
† *Mem. Geol. Survey*, vol. ii, part 1, 1848, p 202.
‡ *Quart Journ. Geol. Soc.*, vol. viii, 1852, p. 136. *Ibid*, vol. ix, 1853, p. 228. *Phil. Mag.*, Ser. 4, vol. viii, 1854, pp. 301, 359, 472.
§ *Quart. Journ. Geol. Soc.*, vol. ix, 1853, p. 161. *Ibid*, vol. x, 1854, p. 62.
|| *Geol. Mag.*, vol. iv, 1867, p. 201.
¶ *Geol. Mag.*, vol. iv, 1867, p. 203.

from that of the Caradoc or Bala of the Ordovician, and the latter authors pointed out that the same fact would probably be demonstrated even along the boundary line in question, and further, that a physical unconformity would be detected between the two systems along this line.

The actual unconformity between the two systems and the striking distinctness of their fossils along this boundary line were, as previously stated, worked out in the field by Aveline and Salter in a convincing and brilliant manner. The unconformable relations of the so-called Upper Silurian to the older rocks below came out upon their maps with admirable clearness, and there is probably no more telling unconformity in the whole of British Geology than that exhibited between the basement beds of the Silurian and the underlying formations in Shropshire. Throughout the whole county the horizontal or gently sloping basement layers of the Silurian rocks creep in turn over every one of the successive zones of the eroded older geological formations, overlap against the hills of the old Silurian land, or fill up the bays between the capes and headlands of the old Silurian sea.

Discoveries among the Strata of the Original "Lower Silurian" Series of Shropshire.

The original "Lower Silurian" rocks of Murchison as developed in Shropshire are at present known to include the true *Cambrian* or "Rocks of the First Fauna" of Barrande and the *Ordovician* system or "Rocks of the Second Fauna"; and within the limits of the Lower Silurian of the county as delineated upon the maps of Murchison and Ramsay there have been of late years discovered, in addition, several rock-groups which are of pre-Cambrian age, or at any rate of an antiquity greater than that of the rocks containing the "First Fauna" or "Primordial Silurian" of Barrande.

Thus the original "Lower Silurian" of Central Shropshire is now known to embrace the following:—

(1) The Ordovician System or rocks of the Second Fauna.
(2) The Cambrian System or rocks of the First Fauna.
(3) The Uriconian or Volcanic pre-Cambrian series of Dr. Callaway.
(4) The Rushton schists of the same author.

Hence if the term "Lower Silurian" is to be retained in the Geology of Shropshire, it must be clearly understood that it can no longer be employed as embracing the local strata for which it was originally used by Murchison and his successors.

In clearing up the maze of formations originally included under the title of "*Lower Silurian*" the original and successful work of Dr. Callaway calls for the first notice.

Cambrian Strata.—*The Shineton Shales.*—In 1854 Dr. Callaway demonstrated by means of the fossils he detected within the district that the Shineton Shales and Green Sandstones of the Valley of the Severn, which had previously been grouped in the Caradoc Sandstone, were in reality of Upper Cambrian age, for they yielded him the typical fauna of the Tremadoc Slates of North Wales and of the Hollybush Sandstone of the Malvern Hills.

Again, as these unequivocal Cambrian rocks were found by him to be underlain by others, the lowest of which rested with unconformity upon the well-known Volcanic series of the Wrekin and the Caradoc Hills, these Wrekin volcanic strata were boldly claimed by him as being of pre-Cambrian date, and were placed by him in a new pre-Cambrian series, for which he proposed the title of *Uriconian*, after the name of the old Roman city in their immediate neighbourhood.

The Olenellus Beds. — While, however, the Upper Cambrian age of the Shineton Shales was unquestionable, owing to the fact that they yielded Upper Cambrian fossils, the Lower Cambrian age of the underlying Hollybush Sandstone and Quartzite below remained still more or less inferential; and it was next requisite to demonstrate their actual Lower Cambrian date by the discovery of unquestionable *Lower Cambrian fossils* within them. This step was made in 1888. In that year Professor Lapworth was able to announce the discovery that a band of limestone, originally detected by Dr. Callaway, in the lower part of the Hollybush Sandstone, contained examples of the genus *Olenellus*, the characteristic fossil of the acknowledged lowest Cambrian of other parts of the world.

The Paradoxides Beds.—The discovery of *Olenellus Callavei* in the Hollybush was soon followed by the discovery of *Paradoxides* (*P. Groomii*), the characteristic genus of the Menevian or Middle Cambrian rocks in the zone immediately above the *Olenellus* band at Neves Castle and Comley.

In this way it became evident that all the three faunal subdivisions of the Cambrian or Primordial system exist in South Shropshire, within the limits of the original Lower Silurian ground; and this discovery necessarily carried with it the final demonstration of Dr. Callaway's original suggestion, that all the rocks of Shropshire older than the Wrekin Quartzite are of pre-Cambrian age.

The Rushton Schists.—In addition to the Cambrian and the typical Uriconian rocks thus detected within the limits of the original Lower Silurian region, there also occurs near Rushton a series of schists or altered flagstones and shales first detected and named by Dr. Callaway, while various gneissic rocks at Primrose Hill are also believed by Dr. Callaway to belong to the same, or to a still more ancient series.

Sub-division of the Ordovician Rocks.—The "Lower Silurian" area of Caradoc and the Wrekin, which these new discoveries have shown to be composed of so many distinct formations, includes a sweep of Bala rocks ranging from the neighbourhood of the Craven Arms to Harnage.

There also exists a still larger area of "Lower Silurian" ground in Shropshire, namely, the extended Shelve District which lies to the west of the Longmynd. The rocks of this Shelve district were grouped by Murchison in his "Llandeilo Series" with the exception of their lowest beds, which were paralleled by him with the Lingula Flags.

This Shelve region has been surveyed in detail by Professor Lapworth, and its igneous rocks have been worked out by Mr. Watts. The district is now known to contain at its base Cambrian rocks (? Shineton Shales) of Tremadoc age, succeeded by the whole of the members of the Ordovician system (with the exception of a few of its higher zones which are hidden beneath the unconformable overlying Silurian to the west).

The sequence in the Shelve area has been brought into line with the Ordovician strata lying to the west of the Longmynd which have also been mapped in detail, and also with the Ordovician formations previously recognised in North Wales, South Wales, Scotland, and abroad.

The net result of all these recent geological researches is, therefore, to show that in the tracts originally constituting the "Lower Silurian" of Shropshire we have strata embracing not only the whole of the Ordovician and the three divisions of the Cambrian as at present understood but, in addition, two important divisions of presumed pre-Cambrian rocks,—the great Wrekin series or Uriconian, and the Longmyndian. All these different formations will of necessity require, in the future, to be delineated by separate titles and colours upon the maps of this southern Shropshire region.

The Longmyndian Rocks (Cambrian of Murchison) and **Uriconian** (Volcanic) **Series.**—Not only did Dr. Callaway separate the Volcanic series of the Wrekin as a distinct pre-Cambrian formation; but he assigned to this Uriconian series the Volcanic rocks of Caer Caradoc and Willstone Hill, which lie to the east of the Longmynd, and also the Volcanic rocks of Pontesford and Linley, which lie to the west of the Longmynd. As these scattered patches of volcanic rocks always intervene between the central mass formed by the axial Longmynd series (the Cambrian of Murchison) and an outer fringe of fossiliferous rocks (the lowest beds of which have been shown, as we have seen, to be those of the Lower Cambrian) it would appear that the Longmyndian series is, in reality, also of pre-Cambrian age. It is quite true that the Volcanic patches thus theoretically assigned to the Uriconian have not all been demonstrated to be of the same age, yet this geographical fact affords a very natural presumption that the axial Longmyndian rocks are, as originally held by Murchison and his followers, the oldest strata in the Shropshire area, and in view of this doubtful position, Dr. Callaway proposed for them the title of *Longmyndian.*

This investigator had, however, already adduced much striking evidence in favour of the actual pre-Longmyndian date of the Uriconian Volcanic rocks; and in 1887 Professor Blake, after working among the ancient rocks of Anglesey, entered with great enthusiasm into the study of the Longmyndian strata, and their relationships to the associated rocks in the Shropshire ground.

As a result of his researches he eventually brought forward a new theory of their stratigraphical position, and supported this theory by a large array of independent observations. After a general survey of the entire Longmyndian region, he showed that the original separation of the enormous basal Longmynd series into two great physical divisions, as suggested in the published works of Murchison and the Geological Survey, appeared fully justified. He held that the great barren Longmyndian series, was divisible into a Lower Grey Shale and Flagstone Series (Eastern Longmyndian), and a Red Sandstone and Conglomerate Series (Western Longmyndian). He concluded that the "Red Sandstone" series is everywhere unconformable to the "Grey Flaggy" series, and that the systematic place of the typical Uriconian Volcanic series of Dr. Callaway is, in reality, between the two; but that it is allied most naturally with the highest or "Red Sandstone" group.

He parallels the "Grey, or Eastern Longmyndian," series with his Monian system of Anglesey, and shows that, as asserted by Murchison and Salter, it is separable into several lithological divisions. The overlying "Red Sandstone Series" he regards as constituting the basal division of the Cambrian system as developed to the west of the main Longmynd axis.

This "Red Sandstone Series" according to his views, represents the whole of the Cambrian with the exception of its higher zones. To the east of the Longmynd, however, according to this author, the equivalents of this "Red Sandstone Series" are exceedingly varied. Here (at the Wrekin, Charlton, Caradoc, and Willstone), the intermediate volcanic series of the Uriconian is present, and its igneous rocks are extruded through the Longmyndians and spread out above them as lavas and ashes. The Volcanic rocks gradually give place locally above to Red Sandstone and Grits formed of the debris of the Volcanic series and these Red Sandstones thicken as they pass to the southwards, until the basal volcanic series dies out altogether, and the Red Sandstone group lies at once unconformably (near Horderley) upon the upturned edges of the grey strata of the "Monian" or Eastern Longmyndian.

The typical Uriconian volcanic rocks are believed by Prof. Blake to be wanting between the "Red Sandstone" and "Monian" series in the central parts of the Longmynd, owing to the great unconformity; while the volcanic rocks of Pontesford and Linley, which lie to the west of the "Red Sandstone" series, are believed by him to be later volcanic rocks intrusive into the Cambrian strata.

In the face of these opposing opinions, we may frankly acknowledge that very much more requires to be done before our knowledge of the Longmyndian and Uriconian rocks is complete. And bearing in mind the excessive difficulty and complexity of the geology of Central Shropshire as a whole, we cannot reasonably expect perfect unanimity and harmony of opinion among geologists, respecting either the true age or natural divisions of these ancient and barren rocks until the whole of the great Longmyndian area and its borders have been mapped out in minute detail.

X. CONCLUSION.

IN this paper a thickness of many miles of strata has been dealt with in some detail, and we desire to acknowledge our indebtedness to the works of those authors to which reference is given in the text. We also wish to express our special thanks to the Geological Society and the Editor of *The Geological Magazine* for the loan of blocks for illustrations, and to the following authors, who have kindly permitted us to make use of them: to Dr. Callaway, for Figs. 2, 3, 4, 5, 7, and 8; Professor Blake, for Fig. 6; Mr. Maw for Figs. 13 and 15; while Fig. 12 is taken from a paper by Mr. Salter.

The general outline of the map, Fig. 1, is taken from the (four miles to an inch) Index Map of Wales, published by the Geological Survey, but the following additional lines have been inserted; subdivisions of the Longmyndian, from Prof. Blake's map; subdivisions of the Cambrian and of the Caradoc sandstone, where inserted, and indication of the Uriconian masses, from Dr. Callaway's maps and papers. Professor Lapworth is responsible for the sub-division and correlation of the Cambrian and Ordovician strata in the map and paper, and Mr. Watts for the account of the Igneous Rocks. With respect to the Uriconian, Longmyndian, and Monian strata, we have simply endeavoured to summarize the views of Dr. Callaway, Professor Blake, Mr. Allport, and Professor Bonney. The pictorial illustrations are taken direct from photographs by Mr. Watts, except Fig. 16, which is from a photograph taken, and kindly given us, by the Rev. D. J. MacLeod.

A. QUARRY AT TASGAR: THE STAPELEY (UPPER ARENIG) ASH-BED, WITH FOSSILIFEROUS SHALES AT THE BASE (TO THE LEFT).

B. SECTION AT HOPE RECTORY: CONTORTED ASH-BED IN THE HOPE (MIDDLE ARENIG) SHALES.

A. Section in Hope Dingle: Hope Shales and Ash-beds (Middle Arenig) in Foreground, Landovery Sandstones in Background.

B. Road-cutting through Wenlock Edge, W. of Much Wenlock, showing Wenlock Limestone.

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NOTE ON A LARGE MASS OF CHALK AT CATWORTH, IN HUNTINGDONSHIRE.

By A. C. G. CAMERON, H.M. Geological Survey.

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[Read 4th May, 1894.]

NO part of Huntingdonshire consists of hills of great height. There are prominent ridges, however, and table-lands in the central districts considerably above the general surface of the county. The Oxford Clay forms the substratum, but the greater part of the county is covered with Boulder Clay, and the valleys are not wholly free from this. It is not a deposit of any great thickness, perhaps not reaching fifty feet anywhere in the county, for the deeper railway cuttings do not hold out in it to their base. Chalk is the principal rock in this clay, and presents occasionally features as phenomenal as they are interesting.

During the latter part of the last century similar phenomena had led to notices of Chalk in Rutlandshire,* nearly fifty miles west of the nearest point where the Chalk occurs in place. At that time it was looked upon as a relic of the Chalk, left after erosion.

Conybeare and Phillips,† writing somewhat later, comment upon the Rutlandshire Chalk, but I take it from the text, that, while fully impressed with the strangeness of the sight, they had at least a shadow of suspicion that the rock might not be in place. Now, the great erratics at Ely, Stoke, Banff, and elsewhere, and the recently-discovered mass of Lincolnshire Oolite, noted by Mr. Fox-Strangways at Melton, show that enormous masses of rock have been moved along and stranded or dropped at great distances from their original site.

My attention was first drawn to a physical peculiarity in the Huntingdonshire boulder-clay by a white heap on the hill-side above Kimbolton, which proved to be pure chalk dug from a pit close by. In this case the outcrop of the chalk did not appear to extend beyond the pit, and there was no evidence of the presence of enough chalk to support more than that pit. Intensely chalky spots like these only occur on high ground, with bigger patches still on the highest summits, to which they form a capping. It would seem as if the old land-surface preserved pretty much the

* *Phil. Trans.*, vol. xxii (1796), p. 179.

† *Outlines Geol. England and Wales*, p. 63 (1822).

same outline in glacial times as now, and that the lower crests, although sufficiently prominent to arrest the smaller blocks and stones, were passed by the great erratics, which grounded where the tops were highest.

North of Abbotts Ripton, the Great Northern Railway passes through a deep cutting in boulder-clay. In the upper part of this cutting there are huge spherical masses or balls of chalk arranged in line.

There is an immense mass or boulder of chalk at Great Catworth, or Catworth-on-the-Hill, an extensive village on some of the highest ground in Hunts, and about ten miles west of the town of Huntingdon. This village presents the unusual appearance of being built upon chalk, though in an Oxford Clay country covered with boulder-clay. The nearest point where the Chalk formation comes to the surface is at a distance of five-and-twenty miles or so to the east. This, however, is only half the distance that separates the site of the Rutlandshire boulder from the Chalk. Judging, however, from the description in the *Philosophical Transactions*,* the Chalk in Rutlandshire is a mass of small size compared to the one now described.

For more than half a mile there is an outcrop of flinty chalk. Outside this area intensely chalky clay or marl spreads out fan-like for half-a-mile; the chalk in it disappearing gradually, and the clay assuming the usual blue colour of the boulder-clay of the district.

A number of pits have been opened in the flinty chalk on account of its valuable property of setting hard like cement when it dries. Many of the yards in the village are laid with it, and there is hardly a barn without a pavement of the sort. The soil in the gardens is chalk, and the graves in the churchyard leave off in chalk.

At the Manor Farm there are several pits in chalk, and Mr. Holmes tells me that in his well the chalk is twelve feet thick, with a never-failing supply of water, which sometimes runs over the top. Outside the chalk area, water can rarely be obtained by sinking in the clay.

Until recently, a band of chalk with flints, about four feet deep, was exposed in a cutting (now defaced) by the roadside adjoining the school. The flints are entire, with no signs of being weathered or worn. Thick tabular masses of flint also lie about the pits where the chalk has been dug, as well as boulders of other rocks, which do not occur in the chalk itself.

It is impossible to say with certainty whether the Catworth Chalk is all one boulder—there may be several, with clay between. At all events this chalk has come *unaltered* from the parent rock, and it is not in any sense of the term a reconstructed chalk.

* *Phil. Trans.*, vol. xvii (1791), p. 75

Boulders other than chalk are scattered over both high and low ground, but are more frequently seen on high tracts than elsewhere. Every village on high ground has its assemblage of boulders, which, however, rarely exceed a yard in length. Some of the softer rocks have been coarsely cut: for instance, the Abbot's Chair, which presents a rude resemblance to a seat, at Stone Chair Cottages, two miles north of St. Ives on the Ramsey road. Other shapes occur near Stukeley. At Brington, a yellow grit, coloured deep red externally, measures $4\frac{1}{2}$ feet, and is 18 inches above the ground. There is another similar but smaller stone at Swavesey-above-Fen. At Old Hurst, and Pidley, there are a number of boulders, principally of Carboniferous rocks, grits and sandstones. One at Pidley, of granitite or syenite, my colleague, W. W. Watts, tells me he cannot match amongst British rocks, the only things at all like it being from Scandinavia. We have, however, a Lincolnshire boulder similar to it.

Another large boulder of granitite with quartz, more like the Skiddaw granite in general appearance than any my colleague knows, lies in the village of Holywell-on-Ouse, on the alluvium of that river, and within the reach of floods. The size of this stone is 4 ft. by 1 ft. 6 in. by 3 ft., and the nearest boulder-clay is two miles off. There is a bed of gravel near, however, from which it might have come.

It is a far cry from Catworth to Holywell, and I should not have wandered thence, for the purposes of this paper, had not Mr. Watts kindly undertaken an examination of these boulders.

P.S.—Since the above was written, chalk has been dug at a well-sinking at the Bone Manure Works, Kimbolton Railway Station. The well-sinkers, after passing through twenty feet of boulder-clay, reached a flinty chalk, in which they left off after digging down in it fifteen feet where they met a spring. As much perhaps as 50 tons of chalk was brought out, of which some 20 tons still lies about, the remainder having been utilised for yard bottoms. Chalk, too, can be seen in the railway cutting a mile west of Kimbolton Station, where it seems to extend to a pond 250 yards distant. It is not possible to say at present whether this is an extension of the Catworth boulder, which lies a mile or so to the north. The amount of chalk found in this district is certainly very remarkable.

Further evidence has satisfied me that there is a Chalk Base to the Boulder Clay in West Hunts and the adjoining parts of Northants and North Beds, the extent of which is far in excess of that previously assigned to it. It is characterised by tabular flint, and in some places by paramoudras. The outcropping edge of this bed sufficiently accounts for the appearance of so much chalk far away from the localities where it occurs *in situ*.

APPENDIX ON SOME BOULDERS COLLECTED BY MR. CAMERON.

By W. W. WATTS, M.A., F.G.S., H.M. Geological Survey.

Old Hurst, Hunts, One-inch Map 187, Six-inch Map 18 N.E. Not sliced. *A quartzose grit*, with shell fragments, probably Mesozoic.

Same locality. Not sliced. A dark *limestone*, with minute Lingulæ.

Same locality. Not sliced. Sandstone. Probably Carboniferous.

Pidley, Hunts, 1" map 172, 6" map 19 N.W. (1 ft. 6 in. by 1 ft. by 10 in.) (Sliced, E 2014). This rock is a *hornblendic Granitite or Syenite*, with very little quartz. The chief felspar is *Microcline*, which makes up the bulk of the slide, there being a little interstitial quartz moulding the felspar. *Sphene* occurs in perfect crystals and in considerable quantity, being associated with a little *green hornblende* and a little *brown mica*; these minerals occur generally in the angular spaces between the felspars, the first mineral impressing its shape on all the others, including the last-mentioned; there are a few biotite flakes in one of the felspars; iron ores are present in small quantity. The rock is greyish buff in tint, and shows felspar crystals varying from quarter of an inch in length down to quite small prisms, some of which are striated: sphene is visible with a lens.

This rock bears considerable resemblance to one obtained by Mr. Lamplugh as a boulder at South Sands, Bridlington, and deposited in the Survey collection. This, however, contains orthoclase and less microcline, less sphene and some apatite, while the ferro-magnesian minerals are a little more plentiful. Mr. Harker* also describes, from Holderness, some granite boulders which are rather of this type, and supposes them to have been derived from a place west of Christiania.

Same locality (1 ft. 6 in. by 1 ft. by 1 ft.). Not sliced. A rough *quartzose grit* like those of the Millstone Grit.

St. Ives and Somersham Railway, Heath Road Cutting, Hunts, 1" 187, 6" 19 N.W. (9 ft. by 4 ft. by 2 ft. 6 in.). A fine grained friable *sandstone*, with quartz and glauconite grains. The extreme fineness of grain, colour, cement, and general character coincide with the Kellaways rock of the district. *The fossils which the boulder evidently contains ought, if collected, to place this beyond doubt.*

Holywell-on-Ouse, Hunts (4 ft. by 1 ft. 6 in. by 3 ft.), 1" 187, 6" 33 N.W. (Sliced E 2017.) Microscopically this rock is a highly quartzose *Garnetiferous Aplite* or binary granite with little ferro-magnesian constituent and a few small garnets.

The felspar is chiefly *microcline* with some *plagioclase* and

* *Naturalist*, 1893, p. 3.

quartz, both being embedded in the microcline, the latter in grains with singularly rounded edges. A few *garnets* and a few small *biotites* are present. A similar rock is described by Harker* from Bridlington Quay, the rounded character of the enclosed quartz being especially noted.

Cold Harbour, Cambs, five miles south-east of St. Ives, 1" 187, 6" 33 N.E. (4 ft. by 4 ft. by 2 ft. 6 in.). (Sliced E 2015.) In general appearance this rock is similar to 2014, but weathers with a whiter crust, and shows much more quartz and biotite. Microscopically it again shows abundance of *microcline*, which contains decomposed felspar crystals which are probably *orthoclase* and a few of *plagioclase*, which latter, where they occur outside the microcline, exhibit an approach to idiomorphism. A good deal of *quartz* occurs, the large grains being strained, the smaller associated as a mosaic, and a smaller quantity of *biotite*, generally in the angular spaces between the felspars. There is no sphene or hornblende in the slice.

Microscopically, but not otherwise, this rock reminds me of the Eskdale granitite in its minerals and structure, a fact noticed by Harker, who, in describing specimen (943) from South of Withernsea, notices minerals and structures like those just noted.

Over Railway Cutting, St. Ives Branch, Cambs: 1" 187, 6" 33 N.E. (4 ft. 6 in. by 4 ft. 6 in. by 3 ft.). (Sliced E 2018.) This is a fine-grained, hard, compact *sandstone*, showing lustre-mottling on broken surfaces, and abundant quartz and glauconite grains on the cut face. It effervesces freely with acids. Under the microscope the structure is very beautiful. There are grains of quartz and felspar, nearly all angular, and varying from $\frac{1}{30}$ down to $\frac{1}{130}$ of an inch in longest diameter. The largest grains of quartz, and some rather smaller of felspar (plagioclase and microcline) exhibit a little rounding. Grains of green or brownish-green glauconite are also present, generally rounded, and sometimes suggesting the forms of organisms; also a few grains of zircon, and of some ferro-magnesian mineral. These are embedded in a cement of crystalline calcite in such large crystals that sometimes the whole of the cement in the field of the microscope extinguishes simultaneously. It is this which causes the lustre mottling of broken surfaces. The cement in the Spilsby Sandstone (Lincolnshire Neocomian), and that of the Kellaways Sandstone of Bedford behave similarly; the grains of the former sandstone are larger and rounder, while those of the latter are smaller and more angular. It is safe to say, however, that the rock is a Mesozoic Sandstone, probably not transported any great distance.

We have, then, as boulders in this district (1) local rocks, (2) those from the Carboniferous region, (3) far-travelled blocks, which cannot have come from a nearer source than the English Lakes, and some of which may have been derived from Scandinavia.

* *Yorkshire Polytechnic Society*, vol. xi, 1889, part ii, p. 306.

THE HYTHE BEDS OF THE LOWER GREENSAND, IN THE LIPHOOK AND HINDHEAD DISTRICT.

By BINSTEAD FOWLER.

[*Read 2nd March, 1894.*]

IN the following attempt to give some idea of the modifications of these beds, I have endeavoured to describe, as accurately as possible, a small tract occupied by the Hythe Beds, including the area which extends from the escarpment overlooking the extreme western limits of the great Wealden Flats at Lyss, and stretching north and east over Liphook to Hindhead and Headley. These beds take their name from Hythe on the Kentish coast, and consist of limestones, chert, and impure sands known as "hassock." Being enclosed between two more or less impervious beds of clay (the Sandgate above, and the Atherfield Clay below), the junction is generally easy to make out with tolerable certainty. As the Sandgate Beds die out just north of Headley, the Folkestone and Hythe Beds are brought together near Churt, Wishanger, and Thursley, north of Hindhead. The Hythe Beds rise rapidly from beneath the Folkestone Sands, culminating in Greyshott and Headley Down, and Hindhead. These beds consist of poor sandy hassock with irregularly bedded rubbly sandstone and small cherty nodules. At Hindhead the sand is a good deal false-bedded, with thin layers of dark greensand. Owing to the lack of calcareous matter in these "hungry" sands, the soil is poor, giving rise to a large tract of common land, and adding to the wild beauty of Hindhead (*cf.* Greyshott, Milland, Lynchmere, Wheatsheaf, Shufflesheep, and Milland Commons). The sandstone and chert are extracted from small pits excavated on the Common and, mixed freely with "Carstone" (a ferruginous grit of the Folkestone Beds), used for road metal. At the hamlet of Hammer, in an old disused sand-pit, are false-bedded brown impure sands, and thin layers and patches of green grains, and irregular courses of slightly cherty sandstone, similar to the wayside sections on the high road at Hindhead.

It is in the Hindhead district that the well-known "Punch Bowl" is situated. It is a good example of one of the many curious forms into which the progress of denudation has carved the surface of the earth. That the scooping-out was done by streamlets and general subaerial waste cannot be doubted, though we cannot follow back the successive stages of the process, and can only guess at the topography of the ground where the erosion began. The Hythe Beds are here at their thickest, being "probably as much as 300 feet" (H. B. Woodward*). The shape of the

* *Geol. England and Wales*, Ed. 2, p. 368.

Bowl is not really circular, but tapers to the west, and gradually sinks beneath the Folkestone Beds east of Churt. The hassocky brown sands and cherty sandstone of the Hythe Beds are exposed in the small cuttings on the sides for about three-quarters of the way down. Here, however, water begins to percolate, and lower down several springs are thrown out by the Atherfield Clay. The horizon of the clay (tapped by denudation) is marked by these springs and a general dampness along the line of junction. The main stream (a small tributary of the Wey) rises at the east end of the Bowl in a large bog. Further west the clay once more disappears, and with it the low-lying swampy ground. The Hythe Beds steepen on either side, and gradually approach, finally dipping almost imperceptibly beneath the Folkestone Beds, west of Thursley.

Towards Bramshott the beds become more hassocky, and are cultivated, but too loose and sandy to form a good soil. Good sections are exposed in the hollow lanes, chiefly consisting of hassock and rag. In some of these lanes (*e.g.*, the Rectory lane) the naked rag forms a natural flooring for some distance.

At Liphook and Lyss the limestone of the Kentish district, known as "Kentish Rag," is evidently replaced by a bluish-grey concretionary limestone, known as "Bargate," the composition and position being similar (Rag $CaCO_3$ 72 per cent.—Bargate $CaCO_3$ 92½ per cent.). It is a bluish-grey limestone of semi-crystalline or saccharoid structure, almost wholly soluble in acid, leaving only rounded sand-grains and thin plates of silica, with a few dark-green grains intermixed. It is generally in lenticular or more or less rounded concretions, and not regularly bedded. It occurs in the upper beds of the Hythe. The following is the section of a well in Liphook village:

	Thickness of Beds. Ft.	Ins.
Hassock—Yellow, impure sands, overlying buff and green-grained sands	14	0
Rag—Or "Sand-rock"	1	2
Hassock—Yellow, impure sands	4	10
Bargate—Not hard—unfit for building	1	7
Hassock—Yellow, impure sands	4	9
Bargate—Harder and better stone than above	1	6
Hassock—Impure sands, with thin courses of Bargate	2	6
Bargate—Very hard; breaks with conchoidal fracture	1	2
Hassock—Compact buff and brown impure sands	4	10
Bargate—Very hard, and in upper layers siliceous	1	8

The large concretionary boulders of Bargate are often brought up in well-sinking round Liphook.

In Mr. Evans' quarry at Lyss is the following section:

	Ft.
Crumbly Bargate	1
Sharp compact sand, false bedded	6
Hard Bargate	2
Sand as above	2
Hard Bargate	3

The sand here is "sharp" enough for building purposes. The Bargate is in wedge-shaped masses with the compact sand in between. It is different to the Liphook stone, being coarser and more friable, but weathering hard. There is also a larger quantity of sand-grains in it; in fact, one might call the Liphook stone all cement and no grit, and the Lyss stone all grit and no cement. Under the microscope the sand-grains are rounded, and "the surface looks like fine ground glass" (Sorby). There are other smaller quarries near Liphook, on Postfield Common, and near Fowley, the interstratified hassock containing a large quantity of sage-green grains. In all these examples the Bargate occurs in the upper beds of the Hythe.

The escarpment of the Hythe Beds is very fine, rising to a great height, and commanding fine views of the vast amphitheatre of the Weald. Like an irregular coast-line, it is carved into deep bays and coombes, or stands out in bold headlands. The thickness of the beds and their varying degree of hardness are probably the cause of the height of the escarpment, for as the rag decreases in quantity in descending the hassock increases. This seems to hold true all along the line—at Hindhead, Lynchmere, Hollycombe, Milland, and Rake. The views from all these places are extremely fine, but the irregularity of the line of the escarpment hides large areas, though perhaps adding to the wild beauty. The sinuous line formed by the base of the escarpment of the Hythe is the outer edge of the Wealden, which looks as flat as the bottom of a sea or estuary, and runs round every promontory and into every bay of the Hythe. The most extensive view and the most interesting is from the high road, about a mile north of Hindhead. From this point the escarpment unfolds to right and left in rugged grandeur; and extending from one's feet the Wealden valley stretches till it meets the sky-line in the blue distance. In the upper beds about here the rag occurs, being highly siliceous, and there are thin bands of almost pure chert. There are also examples of the same beds at Pitfold on the escarpment nearer Liphook.

Ironhill, near Lynchmere, is a good example of the varying proportion of rag to hassock—near the top more of the former than the latter, but lower down the proportion of hassock getting greater and greater, until the rag dies out altogether, and the beds consist entirely of yellow hassock. Lower still the Atherfield Clay crops out, small springs begin to run, the descent becomes less steep and gradually falls into the level of the Weald.

The next good section is at Hatch Lane, just west of Milland. Here the upper beds contain rag and ferruginous strings and shot-like concretions. (These ferruginous lines occur in some quantities in the railway cutting just north of Witley Station.) The hassock here, as in the other sections of the escarpment, gets proportionally greater in quantity as the rag gets scarcer towards the lower beds. A good two-thirds of the way down, the yellow Atherfield Clay crops out, and is seen together with the clayey hassock (?) in a small cutting on the right-hand side of the road, and may be traced in the ditches from this point downwards. Springs are thrown out here as at Ironhill and elsewhere. Just above the junction of the two beds I found portions of fossils (ammonites ?) —all very much broken up and decayed—in greyish clayey hassock. The fossils themselves are of white phosphatic matter very similar to that at the junction of the Gault and Folkestone Beds.

Maysleigh Hanger, near Milland, situated on the escarpment, bears out well what Mr. Topley* says of similar lanes "leading from the high ground to the Weald"—yellow hassock sands containing thin irregular bands of chert and limestone. At Rake, near Lyss, the view from the escarpment over the Weald is very fine, but too much overgrown for any good section to be got at. The view is interesting, however, as showing well the coombes and buttresses carved out of the Hythe Beds, with occasional glimpses of the rounded chalk hills, not rising above but seen through the depressions and gaps in the escarpment.

It is very interesting to walk round the base of the escarpment and note the constant succession of springs and general dampness all along the line of junction of the Hythe and Atherfield Clay.

At New Mill, Shottermill, near Haslemere, is an interesting section exposed in the clay-pits there. At the top is a thin bed of river gravel—waterworn rag, river-sand, and hassock—thinning and dying out northwards. Below this is about four feet of Hythe, consisting of hassocky sands and thin, slate-pencil coloured strings of clay, very similar to those in the Folkestone Beds. Beneath these beds are about fifteen feet of yellow, brown, and buff Atherfield Clay with concretionary nodules of clay-ironstone.

At Shottermill the Atherfield Clay occurs about 5 feet from the surface, being a portion of a tongue of clay passing southwards from the main mass at Haslemere to Hammer village, and forming the bottom of the valley through which the railway lines runs. This clay throws out two fine springs, forming dip wells, in Hammer village. The high ground of the Hythe is covered with gorse and heather, whilst the low-lying clay land is marked by the coarse grass and almost bog-like dampness.

Most of the springs in the Hythe rise in the lower beds and are thrown out by the Atherfield Clay. There are two fine springs at Cotchet Farm and Chase Farm, west of Haslemere. Being farthest from the mouth they may be considered as "the head" of the river Wey. They both rise in deep hollows of the Hythe, and, though not marked on the Geological Survey Map,

* *Geol. of Weald*, pp. 120, 121.

the Atherfield Clay evidently is tapped at Crotchet Farm by denudation, in the same way as at the Devil's Punch Bowl. The high ground of the Hythe, which rises above and around the spring, would form a splendid collecting ground for all rain water, which, kept up by the clay beneath, would reach the line of water level and escape at the point of lowest surface level. There is a similar, though much smaller spring, at Danley Bottom, just west of Liphook, and also at Waggoner's Wells, Bramshott. These all lie in deep valleys in the Hythe.

The rag about Liphook is frequently full of holes like the matrix of a fossil. These can often be seen in the wells and houses built of this stone. Qy.—Are these caused by the decay of Trigoniæ? They are nearly all of the same triangular form, but I have never succeeded in finding the fossil itself, although the rag in the quarry near the railway embankment on Shufflesheep Common contains lots of the impressions.

ORDINARY MEETING.

FRIDAY, 4TH MAY, 1894.

GENERAL MCMAHON, F.G.S., President, in the chair.

The donations to the Library, since the last meeting, were read, and thanks were accorded to the several donors. These included a portrait of the late James W. Davis, F.G.S., from the Yorkshire Polytechnic Society.

The following were elected Members of the Association:—A. J. Maslen; Colonel F. T. Hobson; Rev. G. A. Whidborne, F.G.S.; Miss Dora Abbot; H. St. Barbe.

Papers were read:—

"On a Large Mass of Chalk at Catworth, in Huntingdonshire," by A. C. G. CAMERON, H.M. Geol. Survey.

"On the Distribution and Relations of the Westleton and Glacial Gravels in parts of Oxfordshire and Berkshire," by H. J. OSBORNE WHITE, F.G.S.

Mr. LL. TREACHER exhibited a fine series of palæolithic implements in illustration of the paper.

ORDINARY MEETING.

FRIDAY, 1ST JUNE, 1894.

GENERAL MCMAHON, F.G.S., President, in the chair.

The following were elected Members of the Association:—Harold Blundell; F. W. Lacey; J. M. W. Harrison; R. W. Ferguson.

Professor LAPWORTH, F.R.S., gave a lecture on "Geology and the Relief of the Globe."

ORDINARY MEETING.

FRIDAY, 6TH JULY, 1894.

GENERAL MCMAHON, F.G.S., President, in the chair.

F. C. Fuller was elected a Member of the Association.

A paper "On the Geology of South Shropshire, with Special Reference to the Long Excursion," by Professor LAPWORTH, F.R.S., and W. W. WATTS, F.G.S., was read by the latter, and illustrated by the lantern.

EXCURSION TO LUTON, CADDINGTON, AND DUNSTABLE.

SATURDAY, 26TH MAY, 1894.

Directors: JOHN HOPKINSON, F.G.S., AND WORTHINGTON G. SMITH, F.L.S.

[*Report Deferred.*]

EXCURSION TO NORTH FINCHLEY AND WHETSTONE.

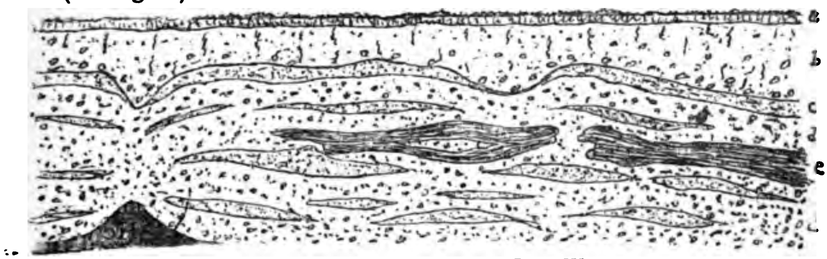
SATURDAY, 2ND JUNE, 1894.

Director: DR. H. HICKS, F.R.S., F.G.S.

(*Report by the* DIRECTOR).

The members first visited the pit in Woodside Park Lane, and were told that since the previous visit in 1887, under the direction of Messrs. J. G. Goodchild and H. B. Woodward, the floor of London Clay had been on several occasions exposed. It was found to be very uneven in surface, as at Finchley and Hendon, the hollows being filled up by rough gravel with masses of sarsen stone, etc. Resting on the gravel there was usually a considerable thickness of stratified sand and upon the latter a brown clay. Over the brown clay, and separating it from the Chalky Boulder Clay, there was frequently a gravel consisting mainly of sub-angular flints. At the north end of the pit the Chalky Boulder Clay was seen to pass down through the sand and gravel, as if in a kind of channel, until it reached the London Clay. This pit is about 300 feet above O.D.

The members then proceeded to Oakleigh Park, Whetstone, to examine an unusually good section recently exposed there. (See figure).



SECTION IN OAKLEIGH PARK GRAVEL PIT, WHETSTONE.
(April 28th, 1894).—*H. Hicks.*
Length about 150 *feet. Depth,* 17 *feet.*

a Surface soil.
b Chalky Boulder Clay.
c Ochreous sand.
d Gravel and light-coloured sand.
e Brown sandy clay.
f Dark brown clay (London Clay).

The Director stated that the brown sandy clay (*e*) occupied here the same position as the brown clay with race at Finchley and Hendon, but that in this pit the lower beds had been disturbed when the overlying sub-angular gravel and Chalky Boulder Clay were deposited. The beds below the brown clay usually contained materials which could only have come from the Tertiary and Cretaceous series in the south-east of England, but in parts of this pit they have been so much disturbed, especially at the north end, that there is frequently a considerable admixture of materials from more northern areas. He believed that the lower deposits had been accumulated in a fresh-water lake during an early part of the Glacial Period. This pit is about 312 feet above O.D.

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EXCURSION TO NORTHFLEET.

SATURDAY, 16TH JUNE, 1894.

Directors: PROF. T. RUPERT JONES, F.R.S., AND F. C. J. SPURRELL, F.G.S.

Attracted by the promised presence of one of our "grand old associates" as Director, a large party assembled at Northfleet and were carried on three light engines to the Northfleet Company's quarry. Here Professor Rupert Jones described to the members the nature and origin of the Chalk, its classification into zones, and the fossils and minerals which it contained. He was followed by Mr. Kirby, who briefly explained the uses to which the chalk and flints quarried at this pit were put. Fossils not having been found in such abundance as to absorb all attention, the votes of thanks to the speakers were at once followed by a move to another pit at Swanscombe.

After hammering here for some time, the party walked on to Greenhithe, some returning at once to London, others remaining for tea. It was explained that although the chalk here abounds with fossils, the collaboration of the workmen is necessary for the acquisition of any considerable collection.

Appended is a report by Mr. Frederick Chapman on the microscopic fossils found in some chalk obtained from the Swanscombe pit.

NOTE ON SOME MICROSCOPIC FOSSILS FROM THE CHALK OF SWANSCOMBE.

By FREDERICK CHAPMAN, F.R.M.S.

DURING the excursion made by the members of the Geologists' Association to the above place on June 16th, 1894, a small specimen of chalk was taken, with the view of testing it for microscopic fossils.

The sample was obtained from the zone of Micrasters, probably the lower portion, or zone of *Micraster cor-testudinarium*. The particular pit from whence the specimen came was the last one visited, and the section of chalk here showed very strikingly the peculiar intercalation, along the planes of bedding, of "some layers of brown sandy clay, sometimes eight inches thick, in parts rather finely bedded," as recorded by Mr. Whitaker,* in a Chalk-pit about one mile S.S.E. of Stone, and which, as he remarks, have evidently been washed down from the overlying beds, through rifts in the Chalk.

Taking into consideration the small quantity of Chalk examined (about two cubic inches), the results, especially as regards the Ostracoda, are particularly satisfactory.

There are twenty-six species and varieties of the Ostracoda, one of which, viz., *Cytheropteron laticristatum* (Bosquet), is new to British Cretaceous deposits; and amongst the number are two undetermined species of *Cythereis*.

Of the Foraminifera there are forty-eight species and varieties. It is a fact worth recording that the inornate species of *Globigerina* are here conspicuous by their almost complete absence, being represented by a solitary specimen of *G. bulloides*, d'Orbigny, whilst *G. marginata*, Reuss — the prickly-margined species—is common. The occurrence of the siphonate form of *Tritaxia*, *T. foveolata*, Marsson, is also interesting, as it is apparently confined to the Upper Chalk; and I take this present opportunity of mentioning its occurrence, with the type species *T. tricarinata*, Reuss, in the Phosphatic Chalk of Taplow, since it was inadvertently omitted from my list.†

* *Mem. Geol. Survey; Geology of London*, 1889, vol. i, p. 82, fig. 5.

† *Quart. Journ. Geol. Soc.*, vol. xlviii (1892), p. 516.

In the list given below, initial references are made as to frequency of occurrence, viz., very rare; rare; frequent; common; and very common.

Ostracoda.

1. *Pontocypris triquetra* (Jones) *v.r.*
2. „ *trigonalis*, J. & H. *v.r.*
3. *Bairdia Harrisiana*, Jones . *v.r.*
4. „ „ var. *amplior*, J. & H. . . *r.*
5. „ *subdeltoidea* (Münster) *r.*
6. *Bythocypris Brownei*, J. & H. *r.*
7. „ *silicula* (Jones), var. *minor*, J. & H. . . *r.*
8. *Cythereis ornatissima* (Reuss.) *f.*
9. „ „ var. *reticulata*, J. & H. . *f.*
10. „ „ var. *nuda*, J. & H. . . *r.*
11. „ „ var. *stricta*, J. & H. . . *v.r.*
12. „ *Wrightii*, J. & H. . *v.r.*
13. „ *sp. indet.* . . *v.r.*
14. „ *sp. indet.* . . *v.r.*
15. *Pseudocythere* (?) *simplex*, J. & H. . . . . . *f.*
16. *Cytheropteron laticristatum*, (Bosquet) . . . *v.r*
17. „ *sphenoides* (Reuss.) *r.*
18. „ *concentricum* (Reuss), var. *virginea*, Jones . . . . . *c.*
19. „ *umbonatum* (Will.) var. *acanthoptera* (Marsson) . . . *r.*
20. *Cytherella ovata* (Römer) . *v.c.*
21. „ *Muensteri* (Römer) *c.*
22. „ *subreniformis*, J.&H. *r.*
23. „ *obovata*, J. & H. . *f.*
24. „ *Williamsoniana* Jones . . . . *f.*
25. „ „ var. *granulosa*, Jones . . *f*
26. „ „ var. *stricta*, J. & H. . . *r.*

Foraminifera.

1. *Textularia globulosa*, Ehrenb. *f.*
2. „ *turris*, d'Orb. . *r.*
3. „ *sagittula*, Defr. . *r.*
4. *Verneuilina triquetra* (Münst.) *r.*
5. „ *spinulosa*, Reuss.. *f.*
6. *Tritaxia foveolata*, Marsson . *f.*
7. „ *tricarinata*, Reuss. . *v.r.*
8. (?) *Spiroplecta annectens* (P. & J.) . . . . . *v r.*
9. *Gaudryina Jonesiana*, Wright *v.r.*
10. „ *pupoides*, d'Orbigny *v.r.*
11. *Bulimina elegans*, d'Orb. . *r.*
12. „ *obtusa*, d'Orb. . *f.*
13. „ *brevis*, d'Orb. . *r.*
14. „ *Murchisoniana*, d'Orb. . . . . . *r*
15. „ *variabilis*, d'Orb. . *f.*
16. „ *obliqua*, d'Orb. . *v.r.*
17. „ *Presli*, Reuss. . *v.r.*
18. „ *elegans*, d'Orb. new var. ? . . . . . *v.r.*
19. *Virgulina Schreibersiana*, Czjzek. . . . . *r.*
20. *Bolivina obsoleta*, Eley, =*B. quadrilatera* (Schw.) . *c.*
21. *Lagena sulcata*, W. & J. . *r.*
22. „ *gracilis*, Will. . . *v.r.*
23. *Nodosaria aculeata*, d'Orb. . *r.*
24. „ *oligostegia*, Reuss. . *r.*
25. „ *consobrina* (d'Orb.) *v.r.*
26. *Nodosaria obliqua* (L.) . . *v.r.*
27. „ *Zippei*, Reuss. . *v.r.*
28. *Frondicularia angustissima*, Reuss. . . . . *v.r.*
29. *Vaginulina legumen* (L.) . *v.r.*
30. *Cristellaria cultrata* (Montf.) *c.*
31. „ *rotulata* (Lam.) . *f.*
32. „ *navicula*, d'Orb. . *v.r.*
33. „ *Gaudryana*, d'Orb. *r.*
34. „ *crepidula* (F.&M.) *v.r.*
35. *Flabellina Baudouiniana*, d'Orb. . . . . . *r.*
36. „ *rugosa*, d'Orb. . *r.*
37. „ *pulchra*, d'Orb. . *v.r.*
38. *Ramulina globulifera*, Brady . *r.*
39. *Globigerina marginata* (Reuss.) *c.*
40. „ *bulloides*, d'Orb. . *v.r*
41. *Truncatulina Ungeriana* (d'Orb.) . . . *f.*
42. *Anomalina ammonoides* (Reuss.) . . . *c.*
43. „ *Lorneiana* (d'Orb.) *c.*
44. „ *rotula*, d'Orb. . *r.*
45. *Pulvinulina Micheliniana* (d'Orb.) . . . *c*
46. „ *repanda* (F. & M.) . *v r.*
47. „ „ var. *concamerata* (Mont.) . *v.r.*
48. *Rotalia Soldanii*, d'Orb. . *f.*
49. „ *exsculpta*, Reuss. . *f.*

EXCURSION TO REDHILL AND NUTFIELD.

SATURDAY, 23RD JUNE, 1894.

Directors: C. J. A. MEYER, F.G.S., AND H. W. MONCKTON, F.L.S., F.G.S.

(*Report by the* DIRECTORS.)

The party reached Redhill Station soon after 3 o'clock in the afternoon, and at once proceeded to a working for fullers' earth about a quarter of a mile east of the station.

The fullers' earth is a hydrous aluminous silicate which does not become plastic with water, but crumbles down into mud. It is used in the process of fulling to absorb the oil with which the wool has been treated in a previous part of the manufacture. The fullers' earth at Redhill occurs in the Lower Greensand. It is also found in the same formation in Bedfordshire, and some fullers' earth works near Woburn Sands in that county were visited by the Association in 1892.* Beds of fullers' earth occur in the Lower Oolites, and the Midford Fullers' Earth Works in that formation were visited by the Association at Whitsuntide, 1893.† Fullers' earth is also found in Saxony, where it is the result of decomposition of diabase and gabbro,‡ and on the north-western side of the Ochil Hills in Scotland, where it is found among the volcanic rocks interbedded with the Lower Old Red Sandstone.

The works at Redhill, which were the first examined, are probably an extension of those at Copyhold Farm, described by Mr. Topley.§ They show a long north and south face of the earth some fifteen feet or more deep, with *débris* of stone beds at the surface. A large block of Barytes was found, and afforded specimens to those who cared for such.

Two other workings were then visited, one north and the other south of the high road from Redhill to Nutfield. In both the earth was seen to be overlain by beds of soft sandstone, with fossils, for the most part badly preserved. Dr. Hinde pointed out that the cherty beds in this pit were largely made up of sponge-spicules.

According to the Geological Survey map, the fullers' earth and also the overlying sandstones are part of the Sandgate Beds of the Lower Greensand, but this conclusion is not accepted by all observers. The subdivision of that formation into Folkestone,

* *Proc. Geol. Assoc.*, vol. xii, p. 395

† See *ante*, p. 126.

‡ Geikie, *Text Book of Geology*, 2nd edit, p. 164.

§ *Geol. of the Weald*, p. 133.

Sandgate and Hythe were first proposed by the late Mr. Frederic Drew. According to Mr. H. B. Woodward,* these names were given in 1861. According to Messrs. A. J. Jukes-Browne and Topley,† 1863 was the date; while in the obituary notice of Mr. Drew in *The Quarterly Journal of the Geological Society*,‡ it is given as 1864. In any case the mapping of these subdivisions of the Lower Greensand in the Redhill country appears to have been the work of Mr. Drew, and as he left the Geological Survey in 1862, the work must have been done before that date.

Meanwhile the attention of Mr. C. J. A. Meÿer, whom we were all delighted to welcome as our Director on this occasion, had been drawn to this formation, and in December, 1868, he read before this Association a paper on the Lower Greensand of Godalming. This paper was in the next year issued as a separate publication and should be obtained by all interested in the Lower Greensand. In it Mr. Meÿer expressed views very much at variance with those of Mr. Drew and the Geological Survey, and when Mr. Topley prepared the notes left by Mr. Drew for publication in the Survey Memoir (which was published in 1875), he refrained from any discussion of the question at issue, and contented himself with the adoption of Mr. Drew's opinions, giving at the same time a full statement of the subsequent opinion of Mr. Meÿer.

During the last two or three years the attention of our Association has been frequently drawn to the Lower Greensand. In 1891, on the occasion of a visit to Guildford and Shalford,§ the correlation of the various beds of that formation was much discussed, and in 1892 the discussion was renewed on the excursion to Wotton,|| whilst of seven numbers of our Proceedings issued in 1893 and 1894 no less than five contain papers or reports of excursions in which the Lower Greensand is dealt with,¶ and in June of this year one of our members has actually carried the discussion on that formation into another place.**

The third working, visited on the 23rd June, was on the east of the grounds of Patteson Court, and about half-a-mile west of Redhill Station. From it an excellent view of the Chalk escarpment is obtained, and Mr. Monckton gave a short account of the general geology of the district, beginning with the highest beds, that is the mass of pebbles mapped as Oldhaven Beds, which are found some 700 feet and more above the sea, on the hills between Merstham and Caterham. He drew attention to the value of the well section at the Caterham waterworks as affording

* *Geology of England and Wales*, 2nd edit., pp. 368-370, 371.
† *Congrès Géol. Internat.*, 1888, Appendix B, p. 66.
‡ *Quart. Journ. Geol. Soc.*, vol. xlviii, Proc. p. 49.
§ *Proc. Geol. Assoc.*, vol. xii, p. 97.
|| *Ibid.* p. 403.
¶ *Proc. Geol. Assoc.*, vol. xiii, pp. 4, 40, 76, 142, 188.
** *Abstract of Proc. Geol. Soc.*, No. 628.

evidence of the thickness of the Upper Cretaceous Beds in the district.*

The party then walked to Nutfield, passing some pits in the fullers' earth east of Patteson Court, which are now almost disused, but have afforded many fossils and where good sections may still be seen. At Nutfield a road-cutting and a sand-pit in the lane down the escarpment due south of the church were carefully examined. This lane is rather more than a quarter of a mile east of the lane section (now much overgrown) described on page 132 of Mr. Topley's Weald Memoir.

Mr. Meÿer stated: That in the sections just visited they had seen the fullers' earth underlying and interstratified with layers of sandstone of the Lower Greensand. In this lane section they saw what appeared to be the beds next below the principal fullers' earth bed, consisting of thin layers of sandstone with traces of impure fullers' earth passing down within a few feet into sand without sandstone, then into a grit-bed with minute pebbles, more or less false-bedded, and then, more or less abruptly, into a reddish, somewhat massive, clayey sand showing little trace of stratification, and apparently of considerable thickness.

As explained on a former occasion,† Mr. Meÿer considered that the sandstone beds enclosing the fullers' earth probably represented the Folkestone stone-beds; that the grit-bed represented the base of the Folkestone beds, and that the reddish somewhat massive clayey sand beneath the grit-bed represented the Sandgate beds of the Coast Section; that the fullers' earth where found elsewhere *in* the Lower Greensand seemed to be on, or nearly on, the same horizon as at Nutfield. And, though not stated as admitting of proof, it was suggested by Mr. Meÿer in conversation that the fullers' earth found in the Lower Greensand might have been derived from the destruction of older beds of fullers' earth (Oolitic), or might possibly have resulted from contemporary volcanic action in the form of dust showers. To this last suggestion, an objection was raised on the ground that no traces of volcanic activity during the Upper Mesozoic era were known in Northern Europe.

Mr. Leighton said he was an iconoclast as to the divisions of the Lower Greensand in this part of Surrey, since he held that the separation of Hythe, Sandgate, and Folkestone Beds was impossible here, as to the two former. The divisions in this typical area rested only upon lithological characters, and since those characters varied from place to place as one proceeded round the outcrop, and since no definite horizon had as yet been absolutely made out, he could not consider this division referred to of any more than local value. If that local classification was

* Whitaker, *Trans. Croydon Microsc. Club*, 1886, p. 48. *Geol. of London*, 1889, vol. p. 42. Woodward, *Geol. England and Wales*, 2nd edit., Appx. 1, p. 612.

† *Proc. Geol. Assoc.*, vol. vi, p. 373.

to be carried to any distance it must be upon palæontological evidence. He understood that the Geological Survey had relied upon a line of springs which was taken as marking the outcrop of the clayey Sandgate Beds, and from that the Nutfield Fullers' Earth was mapped as Sandgate. He hoped, however, soon to bring forward evidence that the Pebble Beds associated with the Bargate Stone of Godalming could be traced into the Nutfield country, where they were found below the Fullers' Earth. It should be remembered that the Geological Survey placed the Pebble Beds at the top of the Hythe, while Mr. Meÿer placed them at the bottom of the Folkestone division, so that there was the whole of the Sandgates in dispute between them. If the country was to be mapped by the springs Mr. Leighton would prefer Mr. Meÿer's classification, because near Godalming the springs occurred below the Pebble Beds, and because the Pebble Beds appeared about Abinger to be intimately associated with the Folkestone Beds. He was not prepared, however, to place the Fullers' Earth in the Folkestones at present (with Mr. Meÿer), but would prefer to call the interesting beds with which it was associated the Nutfield Beds. As to the coloured sands below the Pebble Beds in the Nutfield district Mr. Leighton agreed that they were the same as those which were found on Redhill Common, but he did not see why Mr. Meÿer considered them to be of Sandgate age any more than the cherty sandstone beds of Leith Hill, which also occurred below the Pebble Beds (and were sometimes improperly called Kentish Rag), although claimed by everybody as Hythe.

The bulk of the party now returned to Redhill by another route, passing one or two sections of a less important character on the way.

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1875. TOPLEY, W.—"The Geology of the Weald." *Mem. Geol. Survey.*

See also the papers quoted in foot-notes on the preceding pages.

EXCURSION TO HERNE BAY.

SATURDAY, 30TH JUNE, 1894.

Director: W. WHITAKER, F.R.S.

(*Report by* THOS. LEIGHTON, *corrected by* W. WHITAKER)

From the railway station the party walked to the coast section east of the town, where, before proceeding to the fore-shore, Mr. Whitaker briefly explained the general geology of the district.

The town of Herne Bay is built on the London Clay, which has there a slight dip to the west, so that lower beds rise to the surface as one proceeds eastward. The clay itself yields few fossils, except pyritized wood, pieces of which, washed out of the clay by the sea, may be picked up on the fore-shore. The scarcity of the pyritized fruits, which are so plentiful at Warden Point, in the Isle of Sheppey, has always been pointed to as evidence of the easterly flow of the Eocene river, by which these remains of vegetation were carried into the London Clay sea, the fruits becoming water-logged and sinking nearer the estuary than the twigs and fragments of wood, which occur almost alone at Herne Bay. The London Clay gets sandy towards the base, and there is a six-inch bed of sandy clay with flint pebbles, sharks' teeth, and fibrous selenite. Below this are in places lenticular masses of finely-bedded greenish sand, with small flint pebbles, sharks' teeth, casts of *Natica* and of *Cardium Laytoni*, lying somewhat irregularly on and without passage into the Oldhaven Beds. These two beds form here the basement-bed of the London Clay. The Oldhaven Beds, which are from 18 to 20 feet thick, follow under the basement-bed just mentioned, and consist of fine buff and grey sands, false-bedded, hardened in places into blocks of sandstone and of iron-sandstone, containing marine fossils, amongst which *Meretrix* (*Cytherea*) *obliqua* is conspicuous, and with a pebble-bed at the base varying from a thin layer to one 18 inches thick. Considerable discussion has taken place in recent years as to the correct classification of these beds in the Lower Eocene. Three living geologists have taken part in it, and although they have all developed their opinions somewhat in the course of their writings on the subject, the following may be taken as their latest views.

Prof. Prestwich correlated the beds just described at Herne Bay with his "Basement Bed of the London Clay" in Berkshire and elsewhere, and classed them as the "Upper Members of the Lower London Tertiaries"—not as a part of the London Clay, as the name would suggest; at the same time, the Blackheath Pebble Beds were included by him in the Woolwich and Reading Beds.

Mr. Whitaker correlated the same beds of Herne Bay with the pebble-beds of Blackheath and other places, with the uppermost shell-beds of the old ballast-pit at Charlton, and with beds in other less known localities, as the "Oldhaven and Blackheath Beds," between which and the "Woolwich and Reading Series" he found a "transgression" (? a modified unconformity); at the same time, he included with the London Clay the "Basement Bed" of Berkshire and elsewhere, which, near Reading and in many other places, contains fossils very similar to those of his Oldhavens at Herne Bay. Mr. Whitaker included Oldhaven and Blackheath Beds together, and gave them their local name, because they are sharply separated from the Woolwich Beds below and from the London Clay above, have a distinctive lithological character, and can be separately mapped.

Mr. Starkie Gardner placed Mr. Whitaker's Oldhaven Beds of Herne Bay in the Thanet Sand; in fact, he considered the whole section from the Reculvers up to the junction of the London Clay, near the town of Herne Bay, to belong to the Thanet Sand; also in the Woolwich district he carried the Thanet Beds up to the Mottled Clay of the Woolwich and Reading Series—all with the idea that we have but one set of marine beds in the Lower Eocene.

To return to the Reculvers Section. The pebble beds at the base of the Oldhaven Series are well seen a little to the west of Oldhaven Gap, and at the Gap itself the Woolwich and Reading Beds may be studied when the section is clean. They consist here of grey and pale greenish-grey sand, given by Mr. Whitaker as about 25 feet thick, and contain marine fossils, one of the chief being *Corbula Regulbiensis*, which occurs plentifully in a regular bed. Prof. Prestwich and Mr. Whitaker agree as to these beds. Mr. Gardner's view has been stated above. The Woolwich and Reading Beds here are not clearly marked off from the Thanet Beds, which follow below them, and occupy the remainder of the section as far as the Reculvers. The Thanet Beds however are in great part somewhat clayey sands, and are generally browner in colour; they contain numerous fossils, though not many species, *Cyprina Morrisii* is the most abundant form. Fossils are best collected at low tide along the foreshore, where they may be dug out of the firm, marly sand, when free from surface accumulations. So collected, however, they need care in preservation, since they are very fragile, and saturated with sea water. A good method of collecting and preserving is to take them out with plenty of the matrix, and so place them before they dry into fresh water, in order to extract the salt. When that has been done, and the specimens are half dry, so much of the matrix as is not required to support the specimens should be removed, and a coating of gelatine applied with a soft brush to the exposed surface of the shells. The specimens may then be completely dried, and as much gelatine as they will absorb—a considerable quantity—applied in the same way. Some care is required to prevent the specimens going to pieces; that is the usual result if they are plunged into gelatine when completely dry.

It was noticed that at one part little else than *Cyprina Morrisii* occurred, whilst farther east, in which direction lower beds rise up, *Pholadomya* (? *Koninckii*) was predominant in like way, but farther still the *Cyprina* again came to the front.

A fairly representative collection of the fauna was made by the party before ascending the cliff to the Reculvers, in order to visit the remains of the Saxon Church, and of the Roman Station. A good deal of indignation was expressed at the illegal interruption of the right of way along the cliff at Oldhaven Gap, and the consequent closing of the Gap.

The return journey was made along the cliff-top, where, however, no really good section of the gravel was to be seen; but by the aid of the six-inch ordnance map a fair notion of the cutting back of the coast was obtained. The party also saw a fine example of a mud-flow, of glacier form, starting from small gravel-springs close to the top of the cliff, and winding through part of a well-marked landslip.

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1872. ——————"The Geology of the London Basin." *Mem. Geol. Survey.*

1883. GARDNER, J. S.—"On the Lower Eocene Section between Reculvers and Herne Bay." *Quart. Journ. Geol. Soc.* vol. xxxix.

For previous visits of the Association to the locality, see "Record of Excursions," pp. 57-66.

EXCURSION TO GUILDFORD AND SHALFORD.

SATURDAY, 21ST JULY, 1894.

Director: J. W. GREGORY, D.Sc., F.G.S.

(*Report by the* DIRECTOR.)

The party assembled at Guildford at 3 p.m. It walked thence along the road to Shalford St. Mary's, turning eastward across the fields as soon as the change in the soil, from heavy clay to loam, showed that the outcrop of the Lower Greensand had been reached. The old Pilgrims' Way along the Chantries was crossed, and a path followed towards East Shalford. From a point on this the Director briefly explained the general character of the country and the special objects of the excursion. It was pointed out that at the sections on the coast at Folkestone, the Lower Greensand can be divided into four divisions. At the base is the Atherfield Clay; above this come the limestones (the Kentish Rag) and hassocks of the Hythe Beds; then follows a series of deposits grouped as the Sandgate Beds; and above this are the Folkestone Sands. Traced eastward this sequence of deposits

0° 33′ 35″

51° 13′ 20″

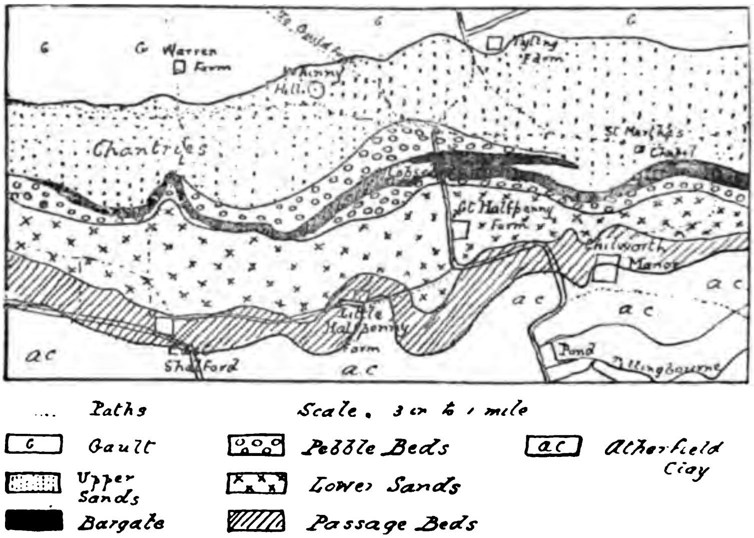


FIG. 1.—MAP OF THE NEIGHBOURHOOD OF HALFPENNY FARM, CHILWORTH.
J. W. Gregory.

undergoes great changes. The Atherfield Clay at the base, and the Gault at the top, remain constant, but the three intermediate deposits repeatedly change their character. Nevertheless the effort has been made to divide the beds between the Gault and the Atherfield Clay into the same three divisions, corresponding to those at the coast. Thus a series of argillaceous bands, fuller's earth, layers of phosphatic nodules, and pebble-beds have been regarded as the Sandgate Beds, all above this line being mapped as Folkestone Beds, and all below as Hythe. The line, however, is so uncertain that great differences of opinion have resulted from this effort to classify these changing series of deposits upon this basis. In this area the sequence is as follows:

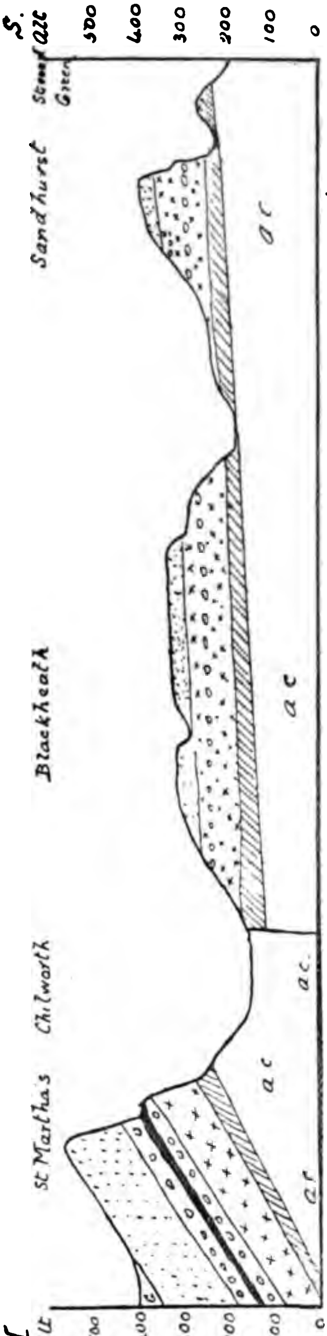
1. Ferruginous sands.
2. "Pebble" Beds.
3. Calcareous Grit, or Bargate Stone.
4. Ferruginous sands; slightly argillaceous.
5. Passage beds.
6. Atherfield Clay.

From the position at which the members stood all these can be seen. The uppermost sands form the crest of the ridge to the north, and are marked by the fir woods. Beds Nos. 2 and 3, here very thin, form a low bank covered by shrubs, running across the fields. The sands, No. 4, form the fields; these slope down to the loam of the passage beds, and Atherfield Clay to the south. Looking westward, one can see the Bargate Beds on the other side of the Wey. Here they are at their thickest, and form a secondary escarpment. Eastward they also become a little thicker. Half a mile to the east, they support a steep escarpment, which can be clearly seen against the skyline. The Bargate Stone is a calcareous grit with a fair number of fossils. It has been correlated either with the Hythe, Sandgate, or Folkestone beds. Meÿer has considered the evidence with the greatest care, and classifies them as Folkestone Beds: he rests his case to some extent on the evidence of the associated pebble beds.

The special objects of the excursion were—

1. To illustrate the above sequence.
2. To trace the thin eastward continuation of the Bargate Stone.
3. More especially to show that the Pebble Beds are not on one constant horizon, but occur either above or below the Bargate Stone, though mainly below it, since farther to the south the Chert series comes in below the Pebble Beds, and on a lower horizon than the Bargate Stone.

The party next crossed the field to the outcrop of the Bargate Stone, which was traced for some distance to the east. The Atherfield Clay was then examined in some sections east of East Shalford. The next halt was at a lane-section in the lower part of Bed No. 4. This is here a sand closely resembling that of the Bed No. 1. A little fuller's earth occurs in it, and the Director had previously obtained fossils from it. This bed lithologically so closely resembles the typical "Folkestone Sands" (Bed No. 1), that on lithological grounds alone one would feel inclined at first sight to refer it to this part of the series. The evidence of this section, the Director explained, was to show the hopelessness of tracing the beds from east to west. One has to consider more closely the evidence of a section from north to south (Fig. 2.) No doubt when these deposits were being accumulated, there was a land area a little distance to the north; these were all a series of shore



Vertical Scale, 1 inch = 400 feet. *Horizontal Scale, 1 inch = 2 miles.*

FIG. 2.—SECTION FROM ST. MARTHA'S ACROSS BLACKHEATH TO STROUD FARM.—*J. W. Gregory.*

For explanation of shading, see fig. 1, p. 378.

deposits. In places a headland ran out into the sea, and in the bay on either side sand quietly accumulated. Elsewhere a river discharged its waters and deposited mud and silt opposite its mouth. In the purer, quieter water, shell-beds were formed, which consolidated into the Bargate Stone. Farther from the shore lived banks of sponges, whose spicules formed great beds of chert; and still farther to the south were yet deeper deposits, which we only know from fragments in the high level southern drift. Hence lithological similarity is no proof of simultaneous formation. These points were further illustrated from the summit of St. Martha's Hill, where a sketch was given of the physical conditions of the area, as far as the evidence of the Lower Greensand demonstrates it. It was maintained that if we abandon the effort to force a classification of these deposits into an artificial scheme, their story becomes more interesting and more intelligible.

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See also "Record of Excursions." pp. 93-102.

EXCURSION TO THE COUNTY OF SHROPSHIRE,

MONDAY, 30TH JULY, TO SATURDAY, 4TH AUGUST, 1894.

Directors : PROFESSOR C. LAPWORTH, LL.D., F.R.S., F.G.S., AND W. W. WATTS, M.A., F.G.S.

(*Report by* R. S. HERRIES, *revised by* W. W. WATTS.)

The headquarters of the Association during the whole week were at Shrewsbury, at the George Hotel. Most of the party arrived on Saturday, and on Sunday the majority took the opportunity of driving out to the Breidden Hills, which, though they are partly in Montgomeryshire, and therefore not strictly within the district proposed to be visited, are so closely connected with it geologically, that the Directors in their recent paper on the geology of South Shropshire* have included them in the area

* *Proc. Geol. Assoc.*, vol. xiii, 1894, p. 297. The references in the text, throughout, are to this paper, and the figures in brackets refer to the map, Fig. 1, p. 299.

which they describe. Mr. Watts, who accompanied the party, pointed out the chief features, the Wenlock and Ludlow Rocks of the Long Mountain, the base of the Llandovery Sandstone, the thick contemporaneous lava-flows and associated ash-beds of Moel-y-Golfa, and the great mass of dolerite on which Rodney's Pillar stands, intrusive into shales of Bala age (see Fig. 11, p. 321). Others of the party went over to Wroxeter to look at the remains of the old Roman town of Uriconium, or spent the afternoon in exploring the Abbey and other fine churches, the old houses, and other antiquities, for which Shrewsbury is justly celebrated.

On *Monday*, *30th July*, the party proceeded by the 10.20 train to Wellington (1), where they were met by Dr. Callaway, who acted as Director during the day, and by some members of the Vesey Club of Birmingham, the Caradoc and Severn Valley Club, and the Shropshire Archæological Society, to whom the Association had sent a general invitation to join the excursion. The Director first led the way to the Ercal Hill, where the granitoid rocks and associated porphyritic rhyolites were examined, and the junction with the Wrekin quartzite noted (p. 302, and Figs. 2 and 3, p. 303). The next point was the quarry at Lawrence Hill with its fine exposure of rhyolitic ashes of the Uriconian series, penetrated by later dolerite dykes (p. 302). The ascent of the Wrekin (2) was then begun, and, after various halts for refreshment, completed; but, unfortunately, owing to the cloudy nature of the day, nothing whatever could be seen of the really magnificent view. A walk along the long S.W. ridge of the Wrekin (Figs. 2 and 3, p. 303; Fig. 7, p. 309) ended with a steep descent to Primrose Hill, where a red gneissic rock occurs, somewhat similar to that seen at the Ercal. At Neves Castle the carriages were waiting, and, after the party had examined the brook and neighbouring quarry in Comley Sandstone, where some of them obtained a few fragments, which they were content to think were portions of the trilobite *Olenellus*, they proceeded to Charlton Hill (4), where the Uriconian conglomerate was well seen (Fig. 4, p. 304), and thence to Rushton (3), where the schists named after the village were not well exposed (p. 301). The drive was then continued to the Lea Rock (5), many specimens of the very beautiful spherulitic rhyolites being obtained (p. 302), and so on to Walcot Station (6), whence the return was made to Shrewsbury by the 7.5 train.

On *Tuesday*, *31st July*, Professor J. F. Blake acted as Director, and the party proceeded by the 10.5 train to Leebotwood (7). They drove first to the village of Comley, the physical features of the district, one of the most beautiful in England, being pointed out on the way. On one side of the valley rise the sharp isolated hills of the Lawley, Caradoc, the Cardington Hills, and Ragleth, while on the other side is the dark mass of the Longmynd, its sides furrowed by numerous "gutters," as these steep-sided valleys are here called. Comley is situated between the Lawley (8) and Little Caradoc (9), and it was from fragments obtained in a quarry here that Professor Lapworth was enabled to make the first announcement of the discovery of the genus *Olenellus* in these islands (p. 310). Several fragments were obtained by the party, who then proceeded in the carriages to Church Stretton (10), where they dismounted and prepared for a long tramp across the Longmynd. Walking up Carding Mill Glen and the Light Spout Valley, the principal divisions of the Lower or Slate Series of the Longmynd were seen. These are now regarded by most geologists as of Pre-Cambrian age, Professor Blake grouping them with his Upper Monian. When the top of the moorland was reached, the party followed the Port Way as far as Pole Bank, where on the western slopes the conglomerate beds of the Upper or Grit Series were well seen. This Upper Series is considered by Professor Blake to be unconformable to the Lower, and he believes it to be of Lower Cambrian age. Dr. Callaway however, differs from him, and fails to see any evidence of unconformity, regarding the whole as one great series, to which he gives the name Longmyndian. Unfortunately, on the return route by Ashes Hollow to Little Stretton, the party started down the wrong valley, and, when they at last got into Ashes Hollow, it was too late to return to what is regarded as a critical section at Narnell's rock, where according to Professor Blake, an outlier of the newer series rests unconformably on the older. It was impossible, therefore, to thrash out the evidence on the ground, and the party proceeded to Little Stretton, whence they drove to Church Stretton and returned to Shrewsbury by the 6.55 train (see pp. 306 to 308 and Fig. 6; and for a general section of the country visited, see Fig. 10, p. 315).

On *Wednesday*, *1st August*, the party went by train at 8.15 to Pontesbury (11), getting a view on the way of various coal workings, and also of Pontesford Hill, an isolated mass at the north end of the Longmynd, which Dr. Callaway has identified as belonging to the Uriconian Series (p. 305). On arriving, the party walked to Nills Hill (12), and examined the quarries in the Stiper Stones quartzite, which forms the base of the Arenig rocks in this district. They then proceeded to a small exposure in a wood a little above Bank Farm, near Minsterley, which shows an outlier of Llandovery rocks, resting unconformably on the Middle Arenig Beds (p. 323). Here many fossils were obtained, including *Encrinurus punctatus*, *Petraia bina*, *Orthis*, *Pentamerus*, *Rhynchonella*, *Tentaculites*, etc. About a mile farther on, at a mine where Barytes is largely worked, the carriages were waiting, and brought the party to Mytton Dingle (14), which they ascended, and were able to collect some fossils from the Mytton Flags, mostly *Obolella*, but *Theca* and *Ogygia Selwynii* were also obtained (p. 317). The drive was continued for some way parallel with the Stiper Stones, of which, with its curious projecting masses of rock—the Devil's Chair, Cranberry Rock, and the Nipstone Rock—good views were obtained; the route was then westwards towards Shelve, and, the carriages being left, the party walked over the various members of the Arenig Series till they reached the highest, the Stapeley Ashes. On the way, several intrusive dykes of dolerite were noticed, also many scattered boulders of the same material. The Shelve anticline then brings up the older beds again, and close to Shelve Church attention was drawn to a bed of graptolites in the Mytton Flags. The walk was continued to the Roman Gravels mine (15), where many beautiful specimens of calcite, barytes, blende, and galena were collected, and after tea the carriages were rejoined and the party proceeded to Minsterley (13), stopping on the way at Hope (16) to examine some contorted beds of finely-banded ashes interbedded with Hope Shales, and another instance of the Llandovery Beds resting unconformably on the Ordovician Rocks (pp. 317 and 323, and Plates VIII B and IX A). These and other interesting sections seen were photographed by various members of the party. From Minsterley the return was made to Shrewsbury by the 6.55 train.

On *Thursday, 2nd August*, the party went by 8.15 train to Minsterley (13), where they arrived in a deluge of rain that kept them waiting in the station for about two hours. When it at last cleared, the long delay had made it necessary to considerably shorten the programme. A start was made in the carriages for the quarry at Tasgar, east of Fishpool (22), where the Ash Beds of the Stapeley group are well seen, with fossiliferous shales at the base (Plate VIII A.) Here the fossil hunters, who had up till now not had much to occupy them, swooped down on the little exposure of shales like a cloud of locusts, much to the astonishment of a small boy, who was in charge of the quarry. One of the members had equipped himself with a crowbar purchased from the Minsterley blacksmith, and with this weapon he turned out enough trilobites, mostly tails, known locally as butterflies, to satisfy the greed of the collectors. The slopes of Corndon (20) were now ascended, and all the way up blocks of dolerite were noted, and the occurrence of these was attributed to the denudation of the great mass of dolerite owing to the undercutting of the soft shale on which it rests. On descending the mountain on the west side, these scattered blocks were conspicuous by their absence, as the outcrop of the dolerite is here covered by overlying beds of shale, and no undercutting has taken place. A halt was made at a section where the dolerite was well seen resting on the altered Hope Shale. The laccolitic character of the mass was explained, and it was pointed out that Corndon was in the direct line of the Shelve anticline, so that the Stapeley Ashes overlie it to the east at Tasgar, and to the west at Llanfawr, while the dolerite itself is intruded into the Hope Shales, and it was shown that the movements that caused the anticline were also the cause of the intrusive mass assuming the laccolitic shape (pp. 341 to 343, and Fig. 22). Farther on, the shales which overlie the dolerite were seen, and these also are much altered; and from a spur of the mountain, which, by the way, is just within Montgomeryshire, a magnificent view was obtained, such as no one would have ventured to anticipate in the morning, while waiting at Minsterley for the rain to stop. To the west the fertile Silurian country of the Long Mountain was seen, bounded in the distance by the Welsh Hills, Cader Idris, the Arans, and the Arenigs, with Snowdon still farther away beyond; to the south the hills of Kerry, the Carmarthenshire Mountains, and the Vans of Brecon; to the south-east the Malvern Hills; while far away to the north the high ground of the Peak district of Derbyshire was clearly visible lying behind the hills of Hawkstone and Grinshill. In the immediate foreground was the country which it had been intended to visit but for the rain of the morning, and the party had to be satisfied with what they could see from this point of the various divisions of the Llandeilo and Bala Beds, forming a series of parallel ridges between Corndon and Chirbury (17). These beds were subsequently visited by a few of the party who remained on at Shrewsbury, and it is satisfactory to know that they confirmed the account of Professor Lapworth, who said that in some of the quarries the trilobites were literally swarming up the rocks like black beetles up a kitchen wall. A descent was now made down the slopes of Llanfawr (19) to Priest Weston (18). On Llanfawr the contemporaneous flows of andesitic lava with porphyritic crystals of augite and hypersthene were examined (pp. 318 and 337). From Priest Weston the party ascended Stapeley Hill, passing over the Ash series, and, noting the old stone circle, known as Mitchell's Fold, came down to the Roman Gravels, where they found the carriages waiting, and so returned to Minsterley in time for the 6.55 train for Shrewsbury. (For a general section of the country visited on Wednesday and Thursday, see Fig. 9, p. 314.)

On *Friday*, *3rd August*, a visit was paid to Shrewsbury Museum, now housed in the old buildings of the Grammar School, where the Mayor kindly received the party, and the collections, both geological and archæological, were explained to them by the Librarian, Mr. Phillips, and others. The latter are particularly interesting, including, as they do, nearly all the Roman remains discovered in the course of excavations at Wroxeter. After thanking the Mayor for his courtesy, the party went to the station, and took the 10.5 train for Craven Arms (23), where they were met by the Rev. J. D. La Touche, who was associated with the Directors during the day. The party followed the Onny River as far as Horderley (24), seeing first the interesting section (Fig. 12, p. 322) where the Trinucleus Shales of the Bala Beds are overlain by the Pentamerus Beds of the Llandovery. The newer series is unconformable to the older one, but, the dip of the two being almost identical, it requires a practised eye and a knowledge of the district to detect the fact. After that, the various members of the Bala series were examined in succession in descending order, fossils being obtained from the Cheney Longville Flags, and the disturbed nature of the beds near the unconformable junction with the Longmynd Rocks, resulting in a good example of a reversed dip, was noted. At Horderley carriages met the party, and brought them back through Craven Arms, and across the outcrops of the Wenlock and Aymestry Limestones to a quarry near Greenway Cross, where the bone bed of the Upper Ludlow was well exposed (p. 328), and large numbers of specimens were obtained by the members. The carriages were left here, and the steep hill of Norton Camp ascended, whence a fine view was obtained over Wenlock Edge, Weo Edge, and the surrounding country, including the Clee Hills, with Coal Measures and intrusive dolerites. The descent was made to Stokesay, where most of the members went over the Castle, a very picturesque fortified mansion of the end of the thirteenth century, after which they returned to Craven Arms in time for the 6.20 train to Shrewsbury.

On *Saturday*, *4th August*, the train was taken at 7.55 for Cressage (28). Walking to Shineton, the party proceeded up the Belswardine Brook (29) to examine a section of the Shineton Shales of the Cambrian, which are probably the equivalents in age of the Tremadoc Rocks. A large number of fossils were obtained here by the members themselves, or bought from the tenant of the neighbouring farm, who brought down a quantity of trilobites, which he had collected from time to time. *Olenus triarthrus*, *Asaphellus Homfrayi*, *Conocoryphe monile*, and *Lingulella Nicholsoni* were obtained among other fossils (pp. 310 and 311.) The party then proceeded to Buildwas Abbey (30), noting on the way the esker-like deposits of glacial sands and gravels (pp. 333 and 334, and Fig. 15), which occur here on both sides of the Severn. At the Abbey Mr. Parker gave an account of the history and architectural features of the monastery. The house was a Cistercian one, and the remains, which include the church, chapter house, and other buildings, are mostly Norman and Transitional in character. Crossing the Severn, an interesting section in the Buildwas Beds of the Wenlock Shale was visited. This forms a small cliff close to the river, and is very full of fossils, mostly small brachiopods, such as *Orthis biloba*, *Orthis hybrida*, and others, as well as small trilobites, corals, and polyzoa (p. 325). The party then took the 1.50 train to Coalbrookdale (32), and examined the railway cutting near the Station, where beds of

Wenlock Shale higher than the Buildwas Beds were seen, and more fossils collected. They then ascended Lincoln Hill (31), whence they obtained a fine view of the Severn Gorge at Ironbridge, and the Wenlock escarpment at Benthall Edge. At the foot of the hill the Wenlock limestone has been largely worked, and many fragments were picked up exceedingly rich in the characteristic fossils, corals, trilobites, crinoids, brachiopods, etc. The Wenlock Limestone is here overlain unconformably by the Millstone Grit, and the Coal Measures come on immediately over that, the Permian and Triassic Beds being seen, overlying all, on the side of the Severn Valley beyond. From Ironbridge Station the party returned to Shrewsbury by the 4.22 train, and then the members dispersed in various directions, thus bringing a very pleasant and successful excursion to an end.

For References, see p. 355.

EXCURSION TO ELSTREE.

SATURDAY, 10TH NOVEMBER, 1894.

Director: REV. PROF. J. F. BLAKE, M.A., F.G.S.

(*Report by the* EDITOR.)

The party assembled at Elstree station just before two o'clock, and the Director led the way at once along the temporary line to the clay tips. He explained that a new tunnel was being made to the east of the existing one in order to complete the quadruple line of railway, but owing to difficulties in connection with the acquirement of land, the clay had to be brought up through a shaft and deposited on the west side of the existing line. The cutting leading to the new tunnel could be seen from this point, but at that distance no stratification could be recognised. Closer examination would reveal a bed of septaria, showing the normal southern dip. The clay in that cutting had yielded him, on a recent visit, a somewhat different fauna from that in the blocks brought out from the tunnel. The excavations would be completed by next March, hence the rather unusual season for this excursion.

The party then spread itself over the ends of the tips, and soon found a number of fossils, not in the best state of preservation, unfortunately. The chief genera found were *Pecten*, *Nucula*, *Teredo* (in wood), *Fusus* (?), *Pleurotoma* (?), *Natica*, *Dentalium*, *Terebratulina* (?), *Ditrupa*, *Nodosaria*, and a fish scale. A heavy fall of rain rendered the clay very slippery, and decided some of the members to continue their fossil hunting in some of the adjacent buildings, where *Nautilus* was found to be abundant. As the daylight faded the members gathered into the station to wait for the 4.53 return train.

NOVEMBER, 1894.

INDEX.